psa

PHOTOGRAPHIC SCIENCE and TECHNIQUE

MAY 1956

Series II, Vol. 3, No. 2

COLOR PROCESSING CONFERENCE ISSUE

Volume Color Film Processing in Practice — John Oliver Brostrup 27

Some Statistical Aspects of Color Processing Control — Spencer B. Fulweiler 33

Equipment for Mounting Color Slides — Eugene G. Seaby 35

The Importance of Accuracy in Stereo Mounting — J. L. Simpson 39

A Slide-Rule for Percentage Masking and Gamma Determination in Color Reproduction Work — Robert R. Erwin 40

A Psycho-Physical Study of Stereo Slide Alignment — M. R. Goff 42

Characteristics of the New Anscochrome Type Printon Film — John R. Kane 53

Processing E. I. 32 Anscochrome Film for Higher and Lower Exposure Indexes — Philip M. Mikoda 55

Sensitometric Characteristics Obtained with Kodak SD-19A Developer — P. Hariharan 57

The E-2 Ektachrome Process: Its Variables and Their Control — A. G. Millikan and N. H. Groet 60

Projection Lamps Easily Identified by New American Standard Code — S. David Hoffman and R. P. Woolery 64

Properties of *p*-Phenylenediamine Color-Developing Agents — John R. Thirtle 66

Thiourea as an Accelerator of the Solution and Development of Silver Halide Grains — T. H. James and W. Vanselow 69

Some Improvements on the Daguerreotype Process of Photography — O. Sherwood Poppe 75

CHNICAL QUARTERLY
FICIAL PUBLICATION
THE PHOTOGRAPHIC
OCIETY OF AMERICA

SUGGESTIONS FOR CONTRIBUTORS

It is the purpose of the technical quarterly to encourage new authors as well as to serve the scientific and technical people who are accustomed to writing for publication. No unbreakable rules have been set for the preparation of manuscripts, therefore, but the following suggestions may be helpful to prospective authors and will facilitate the work of editorial preparation.

ORIGINAL MATERIAL. Every contribution is accepted with the understanding that it has not been published or accepted for publication elsewhere. Occasional reprints, translations from foreign publications, or cases of simultaneous publication may appear but only by special arrangement between the editor and the author.

AUTHORS' COPIES. The Society is a non-profit organization and the technical quarterly has no income from advertising. Papers are published as a service to the photographic public without payment to authors. The author will be sent five copies of the issue in which his contribution appears and additional copies may be purchased at cost. Reprints are provided and may be ordered on blanks provided at the time galley proofs are sent to the author for correction.

MANUSCRIPT PREPARATION. Authors are expected to typewrite manuscripts, double-spaced, on one side of $8^1/_2$ x 11 inch sheets of white paper. At least $1^1/_2$ inch margins should be left on all sides and the sheets numbered consecutively.

REFERENCES AND FOOTNOTES. Bibliographical references should be collected at the end of the paper and numbered consecutively to agree with superscript numbers in the text. Footnotes should be typewritten at the bottom of the manuscript pages, to which they apply and indexed consecutively by an asterisk, dagger, section sign, etc. A brief summary or abstract is recommended. This should appear on the first page, immediately under the title.

ILLUSTRATIONS AND TABLES should be provided on separate sheets of paper and, if possible, should be the same size as the typescript pages. Illustrations should be numbered consecutively and given a caption sufficient to acquaint the reader with the story they tell. Captions should be collected at the end of the manuscript. Tables are numbered consecutively with Roman numerals and should be provided with headings which explain their purpose. Tables should be furnished, each on a separate sheet of paper, at the end of the manuscript.

ENGRAVER'S COPY. Photographs should be on glossy paper and at least 50% larger in size than they will appear in print. They should be identified on the back with the figure number and the author's name. Never put paper clips on photographs. Copy for line cuts should be drawn with India ink on heavy white paper or reproduced as black-and-white photographs from negatives used earlier in the preparation of lantern slides.

EDITORIAL SERVICE. Papers are accepted for publication upon recommendation by the Board of Editors. Every effort will be made to publish them promptly. Unsuitable manuscripts will normally be returned to the author but no responsibility is assumed for contributions. Obvious corrections will be made as a matter of course. In case extensive revisions or additional material are required, the manuscript will be returned to the author with recommendations. New authors may secure rewrite and revision service from the Board of Editors upon request.

Art work of minor corrective nature will be done on illustration copy without charge. Extensive art work or redrawing of charts, etc., will be charged at cost. Authors who have no facilities for preparing charts and graphs may submit sketches and arrangements will be made for providing the necessary engraver's copy.

Series II, Vol. 3, No. 2 ☆ PHOTOGRAPHIC SCIENCE AND TECHNIQUE ☆ MAY 1956

Official publication of the Photographic Society of America published quarterly at 20th and Northampton Streets, Easton, Pennsylvania. Annual Subscription, $2.50. (See below.)
Copyright 1956 by the Photographic Society of America.
Entered as second-class matter at the Post Office, Easton, Pa.

Paul Arnold, APSA, Hon. PSA, EDITOR
26 Hotchkiss Street, South
Binghamton, New York

C. B. Neblette, FPSA, CHAIRMAN
T. D. Publications Committee
65 Plymouth Ave., South
Rochester 8, New York

BOARD OF ASSOCIATE EDITORS

Morris Gurtic, APSA	5412 N. Bernard Street	Chicago 25, Illinois
R. C. Hakanson, APSA	10522 Lake Shore Boulevard	Cleveland 8, Ohio
Hutson Howell, APSA	700 Commonwealth Avenue	Boston, Massachusetts
T. Howard James, APSA	Kodak Research Laboratories	Rochester 4, New York
A. E. Neumer, APSA	635 St. Paul Street	Rochester 2, New York
Elmer S. Phillips	Roberts Hall, Cornell University	Ithaca, New York
John B. Taylor	118 Laurel Avenue	Binghamton, New York

PHOTOGRAPHIC SCIENCE AND TECHNIQUE is dedicated to the publication of scientific and technical papers dealing with the theory and practice of photography. Its aim is to encourage the publication of authoritative articles describing original research, techniques, and the engineering aspects of new equipment in all fields of photography. It is intended to interest and inform the advanced amateurs, the professionals, the technologists, and the scientists who study or apply photographic processes.

Established in 1950, Photographic Science and Technique is prepared under the editorial management and control of the Technical Division of the Society. The first four volumes were issued as Section B of the PSA Journal and numbered 169 to 198 inclusively. As a separate publication, Series II, Volume 1, Number 1 started in the first quarter of 1954.

Members of the Photographic Society of America are entitled to receive both the monthly PSA Journal and this quarterly technical publication. Non-member subscriptions are available only to libraries, schools, and Government units at $5.00 a year ($9.00 for two years) for both publications together. Separate subscriptions are not available. Single copies, including back issues when available, at Society Headquarters in Philadelphia, $1.00 a copy. No extra charge for overseas mailing.

Address manuscripts and communications to the Editor. The Associate Editors are available for advice and assistance in the preparation of manuscripts. Unacceptable manuscripts will be returned if requested. Authors will be sent galley proofs for correction. Reprints may be ordered by the authors prior to publication.

The contents may not be reproduced without the written permission of the editor. No responsibility is assumed for the accuracy of statements by contributors but care will be taken to avoid the publication of errors. The publishing of opinions and conclusions expressed by authors does not necessarily indicate concurrence or endorsement by the editors, by the Technical Division, or by the Photographic Society of America.

VOLUME COLOR FILM PROCESSING IN PRACTICE

John Oliver Brostrup*

ABSTRACT

Processing large volumes of color film to obtain a product of high quality presents problems that are not encountered in handling black and white film. These problems can be solved by meticulous adherence to recommended procedures, by the maintenance of high standards of laboratory cleanliness, and by control checks of the finished product using processing control strips. A method of rapid reading of control strip densities is illustrated and described.

The mission of the Armed Forces Institute of Pathology is stated as: consultation, education, and research. To all three activities color photography makes important contributions, and it is indispensable in the solution of certain diagnostic and research problems. The requirements regarding color fidelity are very exacting and must be met by maintaining high standards when color film is processed in large volume.

Production of color medical illustrative material at the Armed Forces Institute of Pathology has grown from 7,400 items in 1945 to 60,000 in 1955. All of the 1945 production was on Kodachrome, which required no processing at the Institute. Approximately half of the 1955 production was on Ektachrome, which must be processed immediately within the facilities of the Institute. The prospects are that both total color production and the proportion locally processed will continue to rise.

More than half of the color work is duplication, in which every effort is made to match the original color transparency. This requires close tolerances in color processing. Because of the adaptation of the human eye, original color transparencies can deviate as much as one .10 color compensation filter and still be acceptable to most viewers; but when an original is compared side by side with a duplicate on the same light source, deviations overall of one .05 color compensation filter can be detected by most viewers.

The factors bearing upon the production of color film transparencies of high quality are varied and complex. Some of these factors are easily controllable. In the production of film, the manufacturers limit permissable deviations to the order of a CC .10 filter from their standard for an ideal product. Other factors, particularly storage and exposure conditions, are not so easily controlled.

With the release of color films that can be processed by small laboratories with relatively little control equipment as compared with Kodachrome, and with a growing use of these films, thoughtful attention must be given all those details which during processing can contribute to high fidelity color. Questionable methods employed by the color film processor should not be superimposed on the many hazards that the amateur and professional must encounter in making color photographs of excellent quality. The consumer is certainly entitled to receive a product that represents the ultimate in controlled processing conditions within the bounds of economic practicality. Many of the controls are dependent upon judicious supervision of processing equipment, techniques and personnel.

This paper represents a synthesis of ideas and experience accumulated by the author and his colleagues during ten years spent processing color film in large volume. The laboratory layout, equipment and methods herein described are not necessarily those currently in use at the Armed Forces Institute of Pathology, nor does any statement concerning equipment or methods constitute an endorsement or recommendation.

Laboratory Layout

The color film processing during an average day at the Armed Forces Institute of Pathology is 300 to 500 sheets of 4 x 5 film, or the equivalent square footage of 8 x 10 film, per eight-hour work day of one person on the processing line. When unusual demands have necessitated overtime work, the maximum output was 700 sheets in a day, with one person working on the production line from 8:00 A.M. to 4:30 P.M. and another from 4:00 P.M. to 12:30 A.M. The person on the processing line also mixes his own solutions and is relieved at a break during the morning and afternoon, and at lunch period.

An ideal layout for sheet-film processing is shown in Figure 1. Since one person must operate the entire line, and the volume of production requires trains of batches of film going through the line, it is essential that both the inner (dark) area and the outer area be light proof. Expiration of developing times may require the operator to move from Area 1 to Area 2, sometimes in total darkness. The entrance to the whole line should be through Area 2, thereby allowing unprocessed and processed film to be carried in and out while developing is going on in total darkness in Area 1.

On the door jamb just inside Area 1 there is a small signal box marked "S" on Figure 1. In this box are mounted two 7-watt candelabra lamps, separated by a light-tight divider and covered with a metal plate perforated by two holes, 1/8" in diameter, one over each light. Behind one hole a dark red filter and several neutral density filters make this light just visible in total darkness. Behind the other hole is a dark green filter and neutral density filters. The red signal lamp is wired to the light fixtures in Area 2, all being on one circuit. The green signal lamp is wired to a microswitch (SW on Figure 1) on the door from Area 2 to the rest of the photographic laboratory, so that it burns when the door is closed. With these signal lamps in operation, if work is progressing in total darkness in

* Photography Division, Armed Forces Institute of Pathology, Washington, D.C. To be presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York, 25 and 26 May, 1956. Received 5 April, 1956.

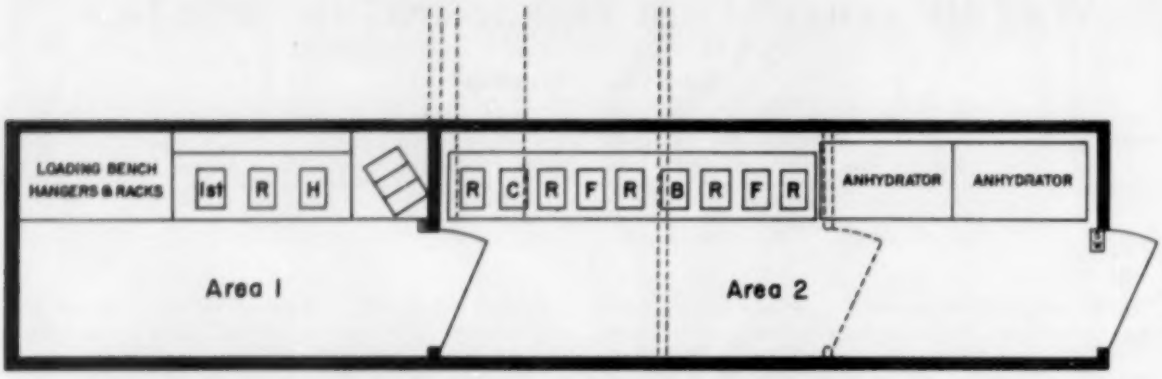


Fig. 1. A suggested laboratory plan for color film processing.

Area 1, the green light on the signal box must be burning and the red light must not be on when the door to Area 2 is opened.

An alternative plan for the processing line is indicated by hatched lines in Figure 1. If it is necessary to swing Area 2 90 degrees, this represents the best plan as it minimizes the movement of processing cages from the hardener to the next rinse. The film drying cabinets can be located in an adjoining room, but are ideally placed immediately after the final wash.

Air conditioning in the laboratory housing the processing line is highly recommended. It will facilitate temperature control of the processing solutions, provide clean circulating air, and contribute to the comfort of the operators.

The laboratory layout for processing 35mm color film depends on the type of equipment and availability of space. At the Armed Forces Institute of Pathology film of this type is almost entirely in 50 ft and 100 ft lengths and is handled on Nikor reels. In general photofinishing operations, strips of these lengths are seldom processed. Several different types of equipment for processing short length color film are available and the floor plan for each of these will have to be individually determined. In locating this equipment the outer, normally light area should be partitioned so that in emergencies it can be totally darkened to facilitate access to both areas under "blackout" conditions. Use of a maze or double doors is not a good substitute, for it increases the distance from the hardner to the next rinse, which should be kept to an absolute minimum.

Hot, tap, and chilled water in ample supply are essential to high quality color processing, and the pressures of all three lines must not jump or drift as other demands are made upon the systems. Filter systems must be installed if finely divided sand from water purification plants, rust and other contaminants are present.

At any instant there may be from two to four 3½-gallon capacity rinse tanks in operation on the one Ektachrome sheet film line alone. Each of these rinses requires at least three gallons per minute, making a total minimum requirement of twelve gallons per minute. This amount is exclusive of the water used in simultaneous processing of 35mm film and other operations.

Tap water in Washington, D. C., varies from about 45 F in January to about 85 F in August. Water on the sheet film line should be tempered to 75 F. For winter operations the temperature of hot water should be 130–140 F and for summer operations chilled water should be 40–50 F. Even with adequate supply and constant pressure it is difficult to maintain 75 F in the spring and fall when the tap water is near 75 F. In spite of possible inefficiency, at least in Area 1, it is necessary to mix hot water with chilled water during these transitional periods until the tap water is either below 70 F or above 80 F.

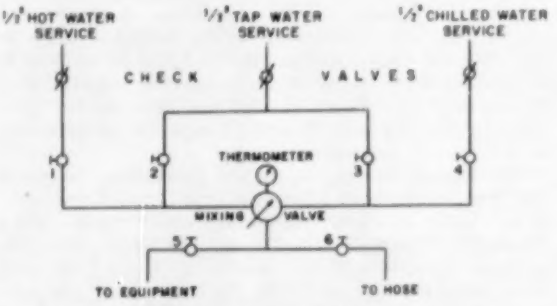


Fig. 2. Plumbing schematic diagram for proper maintenance of solution temperatures in color processing.

Figure 2 shows a typical plumbing schematic. There should be a separate mixing valve for each area.* For summer operation, Valves 1 and 3 are closed, Valves 2 and 4 are open. For winter operation Valves 1 and 3 are open and 2 and 4 are closed. Most city codes require check valves where there is an installation of mixing valves, and also where there is no air space between contaminated water lines and supply lines. While check valves reduce pressure slightly, they are absolutely necessary in color film processing installations.

* The nominally priced mixing valves do not correct for erratic changes in pressure. Mixing valves manufactured by Lawler and Powers are satisfactory.

The mixing valve thermometer should have a luminous pointer with a luminous mark at 75 F. In a large, continuously operating installation it is advantageous to have a recording thermometer in each of the two developers as a further control measure. All thermometers should be checked periodically with a precision mercury thermometer. Recording thermometers selling under $50.00 are now on the market.

If there are individual valves at each rinse tank, Valve 5 is not required. The individual valves for each rinse are shown in Figure 3. Water is flowing in any rinse only when that rinse is in use. Valve 6 and a hose that will reach all tanks is useful when flushing out old solutions and mixing new ones.

Drains from Area 2 should be made of rubber hose or plastic pipe until the bleach rinse reaches a point at which dilution with rinses from other areas will no longer cause serious corrosion of commonly use galvanized pipe. The trap immediately below the rinse after bleach will be a problem unless fitted with rubber hose or plastic pipe. All plumbing should be easily accessible for servicing. If possible, color film processing units should be located in areas where possible overflow or leakage from a tank that may give way in off-duty hours will not cause serious damage. A ceramic tile floor with drain is a good precaution. With tile or cement floors, however, $^3/_8$ inch thick rubber rugs are a necessity for the comfort of personnel who must be on their feet all day.

The requirements for electrical current generally are not high. A separate 20 ampere box with large pull handle switch is used for switching on and off the second exposure light. All equipment including timers, second exposure light boxes, etc., should be adequately grounded.

Sheet-Film Color Processing

The precautions specified by the manufacturers of color film should be observed under close supervision.

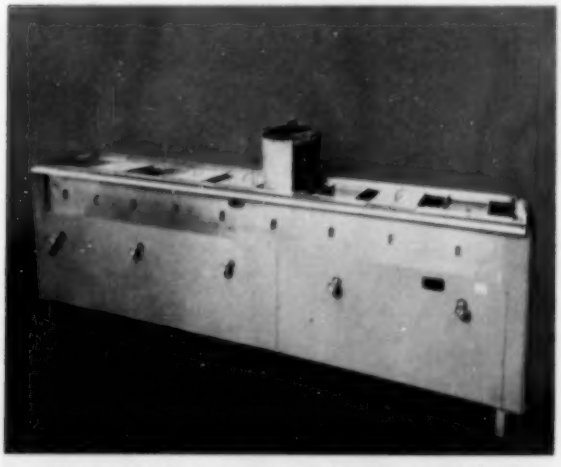


Fig. 3. Grafic vane agitation equipment. A batch is about to be lowered into the bleach solution. Plastic covers protect the solutions from contamination when not in use.

All solutions should be properly mixed and free from contamination.

Ektachrome color developer chemicals should be dissolved in the recommended volume of water. Before any equipment is used the total final volume of all solutions should be measured with an accurate graduate and indicated on or near each tank. Careful supervision should be exercised to ensure that the solutions are prepared in the exact volumes specified.

Only 4 x 5 and 8 x 10 sheet-films are processed on the E-1 Ektachrome processing line. Occasionally larger sizes up to 24 x 30 are processed in trays. Four by five inch film is developed in multiple hangers. A batch consists of ten hangers of either 4 x 5's or 8 x 10's, or any combination of the two.

A processing control strip is included with each batch. To carry this strip, special combination hangers were made from the regular 4 x 5 Kodak No. 4A film hangers and the special hangers made by Kodak for carrying processing control strips. Each hanger consists of one control strip hanger and two 4 x 5 hangers, cut, combined, and spot welded into a unit. On six of these units the 5 x 7 control strip hanger was located below the two 4 x 5 hangers, on six others the control strip hanger was located above the two 4 x 5 hangers. For continuous processing of batches of film, including drying time, twelve of these special combination hangers are required.

A typical batch of ten hangers consists of one control strip, thirty 4 x 5's and two 8 x 10's or any other combination of a special control strip hanger, 4 x 5 multiple hangers and 8 x 10 hangers.

Storage racks for hangers are located over the loading bench in Area 1. While developing is proceeding, hangers are loaded and placed in "dry" 8 x 10 hard rubber tanks with light-tight lids. On Friday afternoons all hangers and reels are given a soaking in a hot sodium carbonate solution to remove emulsion that may have stuck to the channels or wire guides. This is followed by a thorough wash in hot water.

There are several compelling advantages to having film remain in the solutions during processing. The Grafic vane agitation equipment shown in Figure 3 has proved consistently reliable over a long period of continuous use. The constant movement of the vanes at eight cycles per minute was found to provide too much agitation. A Graylab universal timer was altered to trip the Grafic vane agitation at a cycle each thirty seconds. A supplementary bypass switch closes the circuit to give continuous agitation during the first thirty seconds a batch is in any solution and also to stir the solutions before processing is resumed after a break of several hours.

Processing times are the same as recommended for Ektachrome sheet film in E-1 solutions, with the exception of the rinse after first developer. This rinse is given $1\frac{1}{2}$ minutes with a plus or minus 10-second tolerance, and is required to avoid alum scum. Perhaps this scum forms as a result of the characteristics of Washington, D. C., water; however, with this $1^1/_2$-minute rinse there has been no trouble with alum scum or reticulation. The times in first developer and color developer are changed as the solutions are used. Figure 4 shows the dial record that is kept of films processed through a given mix of $3^1/_2$ gallons. The capacity of $3^1/_2$ gallons

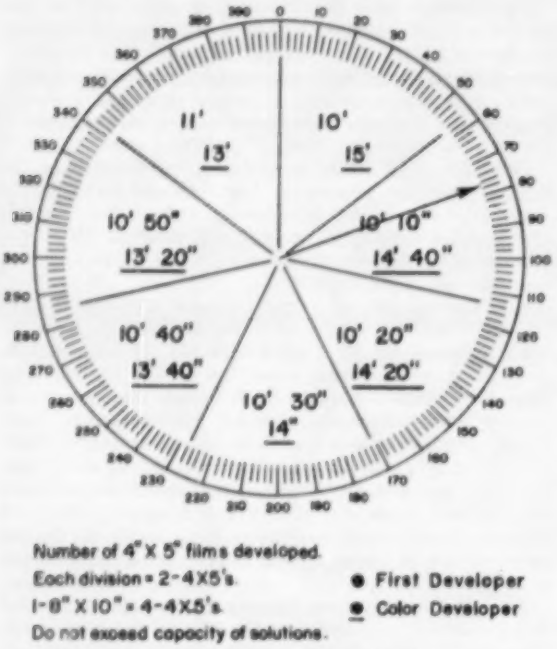


Fig. 4. Dial for recording the number of units processed in a given mix.

of E-1 solutions is 400 sheets of 4 x 5 film. Immediately before a batch is placed in the first developer the pointer is advanced to indicate the number of units about to be processed. The zone in which the pointer falls determines the first developer and color developer times, thus when the second batch of 38 sheets of 4 x 5 film plus its control strip is about to go into the first developer, the pointer will be set at 77 and the times for this batch will be 10'10" in the first developer and 14'40" in the color developer. (The control strip is counted as half a sheet of 4 x 5.) Individual luminous-dial interval timers are located immediately above each solution and each rinse tank. Because of the critical nature of the first developer and color developer, large luminous-dial timers are used above these tanks.

The temperature of the solutions is brought to 75 F plus or minus $^1/_2$ degree. Area 1 is darkened and a developing cage is loaded with ten hangers. The hangers must be placed so that all emulsions face the vanes. It is advisable NOT to have an 8 x 10 hanger and a multiple 4 x 5 hanger face the same vane as eddy current marks may show up on the 8 x 10 film. The cage is lowered into the first developer, the clock is started, and the constant agitation switch closed. After thirty seconds of constant cycling (four cycles), the intermittent cycling clock is turned on and for the remainder of the time there is a vane agitation cycle each thirty seconds. About twenty seconds before the end of the prescribed developing time the cage is withdrawn from the solution and drained from one corner. Precisely at the expiration of the specified time it is immersed in the next tank and the clock set for this rinse. This technique is used in each solution or rinse, immersing cage and setting timer, draining cage for fifteen seconds, and immersing in the next tank precisely at the end of the prescribed time.

Second exposure of sheet film is done by holding each hanger in the second exposure box for a total of four seconds. See Figure 5. Outside dimensions of this box are 12" x 18" x 12". In each section there is a 500 watt, 3200 K lamp covered with a sheet of opal glass. When the hanger is withdrawn from the hardener, it is shaken vigorously and tilted at an angle causing the film to lie against one side of the hanger channels. The hanger is held in the second exposure box at that angle for two seconds. It is then shaken and tilted to an opposite angle that will allow the film to lie against the other side of the hanger channels. This technique is rapid, does not require removal of film from the hangers, and gives adequate second exposure out to the edges of sheet film.

If only one person operates the Ektachrome sheet film line, the starting time of each batch must be considered. As soon as a batch is transferred to the color developer a new batch is started in the first developer. With the starting time of a batch in the first developer geared to starting a batch in the color developer, no conflicts arise in starting and terminating times for any of the solutions or rinses.

In order to have a continuous uninterrupted line, the following technique is used to furnish two separate clear and fix solutions. Upon exhaustion of a mix of solutions, all are discarded except the clear and fix solution following color developer. This solution is moved down the line to the position following the rinse after bleach. This technique has been followed for five years without difficulty.

Developing times and procedures recommended by the manufacturer generally are followed but it has been found that the rinse after the first clear and fix should be held to a plus or minus ten second tolerance. For a final rinse, Photo-Flo should be used for Ektachrome and

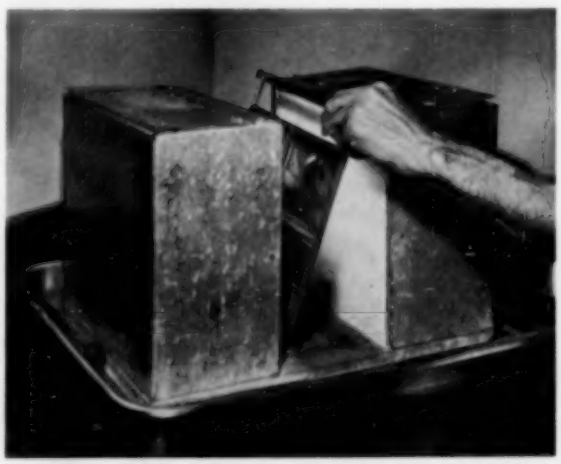


Fig. 5. Hanger held at an angle while in the second exposure box.

Fig. 6. Densitometer and strip recorder used at the Armed Forces Institute of Pathology laboratory.

Glim for Anscochrome. In this laboratory with forced drying, this rinse is required to avoid water-soluble residues and water spot drying marks. Two Oscar Fisher Anhydrators are required to handle a batch of sheet film every half hour plus a 100 ft roll of 35mm E-2 Ektachrome every two hours. When a new batch of film is about to be placed in the drying cabinet, the previous batch is moved from the lower to the upper level so that water droplets do not fall on partially dry film. E-1 Ektachrome will be completely dry in 45 minutes, E-2 Ektachrome in 30 minutes. When first put into operation the Oscar Fisher Anhydrators should be very thoroughly cleaned with a vacuum cleaner to remove fine particles of the drying chemical that get out into the drying area during shipping.

The only 35mm color film processed is bulk E-2 Ektachrome that has been exposed on the 35mm duplication bench described in a paper delivered at the October 1955 meeting of the Technical Division of the Photographic Society of America.* This film is processed in 35mm 50 or 100 ft Nikor reels loaded in the special loading stands. The film is not removed from the reel from the time of loading until completion of processing and drying. The emulsion of E-2 Ektachrome does not stick to the guide channels of the Nikor reels even with forced drying. The reels are ready for the next loading immediately after removal of dry processed film. Second exposure is accomplished by placing the reel in a dry tray two feet from a #2 Reflector Photoflood for 20 seconds on the first side and 15 seconds for the other side. The Photoflood should be protected by a sheet of glass to keep water droplets from splashing on the lamp and possibly causing it to shatter.

Recommended processing times for E-2 Ektachrome are followed precisely and there is no change in times of processing in any solution with attrition of the mix. Agitation should follow a precise and unvarying routine to ensure uniformity. Over-agitation causes a lighter than normal transparency while less than normal agitation results in darker transparencies. In both cases color shifts result. Agitation is accomplished by drawing the reel to the top of the developing tank and lowering it repeatedly during the first fifteen seconds in each solution; after that it should be raised and lowered once only at intervals of one minute. The reel should never be rotated. The solutions are not used beyond the fourth day after preparation. One gallon of solution will process 170 ft of 35mm E-2 Ektachrome.

Nitrogen burst agitation appears to be a very attractive development and it may be installed to increase productive capacity further. Incorporation of this system into the present equipment at the Armed Forces Institute of Pathology would necessitate the installation of gas distribution manifolds in every solution tank, because at any instant as many as four solutions may be in use. Nitrogen burst would be used for the two developers and compressed air for all other solutions. Water-pumped nitrogen must be specified; oil-pumped nitrogen cannot be used for film processing.

Processing Control

As a check on color processing standards, an Ektachrome Process Control Strip is included with each batch of film. These strips are shipped from Rochester by Air-Express packed in dry ice, and are kept at 0 F until the day before they are used. The use of these strips, together with tri-linear[1] and chronological[2] plotting, gives conclusive evidence of the quality of color film processing. Color film should be key coded to the control strip with which it was processed. This method provides a permanent record which can be used to establish the adequacy of a processing run that might be questioned.

The objection to the use of control strips has been the length of time required to interpret results. This objection has been overcome and the considerable advantages of using control strips have been realized by adoption of the following techniques. The five to twelve control strips processed daily can be read, computed and plotted in a half hour by using an Ansco-Macbeth Model 12 color analyzing densitometer together with a Brown Strip Recorder Model Y153X12(X)-X-(6). See Figure 6. Only one color analyzing densitometer is used for control strip reading as each has its own characteristics. An O-30 scale for the Brown Strip recorder is part No. 77078-5405N and O-30 chart paper is stock No. 5405-N.

The method of connecting the strip recorder to the densitometer is described in the manual for the densitometer. This hook-up was altered to the extent of using two double-pole double-throw switches. This instantaneous switching arrangement makes readily available either the densitometer or the strip recorder. Since the color analyzing densitometer is used for other work, instantaneous switching between it and the strip recorder is necessary. These switches are ganged with a piece of bar metal and when thrown in one direction put the densitometer scale in operation, when thrown in the other, activate the strip recorder scale. Both cannot be used simultaneously. The toggle switch next to the ganged switches controls transmission or reflection density readings. The chart drive switch was moved out of the recorder and is the top toggle switch.

* This paper will be published in Photographic Science and Technique.

The strip recorder sensitivity control is the shaft located in the center rear of the recorder side panel. Both these instruments are adequately grounded.

In use the densitometer and recorder are adjusted to the proper zero and sensitivity control settings as specified in the instruction manual. With the strips in proper sequence, first all red-light densities, then all green-light densities, and finally all blue-light densities are recorded in order. From the data recorded on the Brown Strip Recorder, computations and plotting are done as described in references 1 and 2. Experience at the Armed Forces Institute of Pathology indicates that deviations from the control strip processed by Kodak rarely exceed a .10 CC filter, normally not over .05 CC. The drift with attrition of a mix is in the direction of increased magenta. It is pointed out that E-1 solutions usually become exhausted daily and always by the end of the second day. Since there are no operations on Saturday or Sunday, a given mix may possibly be used Friday and the following Monday, but usually this procedure is avoided by proper management of processing schedules.

In connection with the examples given in reference 1, it is to be noted that the grouping of the plot points need not be centered at the intersection of the C-Y-M axes. Depending upon the particular color analyzing densitometer and the characteristics of its individual filters, the grouping may be in any sector of the plot plan. The point is, that the plots for locally processed strips should be as close as possible to the plot for the Kodak processed strip and should not drift beyond, say, a 0.10 distance away from it.

Since the plots of control strips at the Armed Forces Institute of Pathology normally are within a 0.10 tolerance, and the color film processing does not operate on a replenishment schedule, the chronologic plotting described in reference 2 is not done. When increased volume of E-2 processing necessitates a replenishment schedule for these solutions the chronologic plotting will be a great aid to quality control.

A new method of quality control was announced by the Kodak Company in November 1955.[3] This new system has not yet been adopted at the Armed Forces Institute of Pathology because an ample supply of original type E-2 control strips is on hand.

Interpretation of the new control strips promises to be more convenient and rapid than the old system. The equipment for taking rapid readings of many strips herein described can still be used to good advantage with this new quality control procedure.

Summary

The procedures described have resulted in color film processing of uniformly high quality. Major factors contributing to success are (1) judicious supervision; (2) adherence to recommended procedures, especially with respect to solution capacity, total volume when mixing and rigid uniformity of processing times and frequency of agitation; (3) laboratory cleanliness and freedom from contamination, and (4) control checks by the use of processing control strips.

References

1. Eastman Kodak Company: Trilinear Plotting for Kodak Ektachrome Film Process Control, 1955.
2. Eastman Kodak Company: Chronological Plotting for Process Control, 1955.
3. Eastman Kodak Company: Quality Control, Process E-2, Kodak Ektachrome Film, Publication Y-40, 1955.

BIOLOGICAL PHOTOGRAPHERS' MEETING

The first five-day meeting in BPA history is scheduled to be held in Rochester, New York, August 27 to 31, with headquarters at the Powers Hotel. This 26th annual meeting of the Biological Photographic Association, Inc., celebrates a quarter century of professional service to research organizations and the healing arts.

General Chairman John J. Beiter (Rochester Hospital) has scheduled a day-long session on color photography, materials and processes, followed by technical paper sessions, field trips, and exhibitions of prints, slides, and motion pictures.

NEW WESTON EXPOSURE METER

A new model of their popular photoelectric exposure meter, claimed to have greatly improved resistance to shock damage, has been announced by the Weston Electrical Instrument Corporation. Named the Master III, the new meter incorporates design features which have been employed in Weston precision instruments to safeguard their accuracy and prevent damage under military field conditions. The meter movement is "cushion mounted" within the case and the jewel bearings for the pivots ride on shock-absorbing springs.

The calculator dial has been redesigned to make use of the American Standard Exposure Index numbers for designating film sensitivity. Additional provisions have been made for the non-standard lens aperture markings of the Polaroid cameras and for the arbitrary scale of numbers found on LVS shutters recently imported from Germany.

Weston Master III calculator dial showing new style easy-to-read-numbers and indication for Polaroid cameras and Dekel LVS shutters which do not grade relative apertures in the conventional f/numbers.

SOME STATISTICAL ASPECTS OF COLOR PROCESSING CONTROL

Spencer B. Fulweiler*

ABSTRACT

Profitable color operations require adequate process controls. Statistical methods are applied to controls and it is shown how statistics, gathered over a period of time, are utilized in establishing the basis for the necessary controls.

STATISTICAL ANALYSIS in color processing control is used to provide a basis for action with regard to the production process with a view to future work—should processing conditions be left alone or should action be taken to find and eliminate the disturbing causes.

W. E. Demming, in an article on Shewhart's methods of quality control, makes some sound observations with reference to the problem. He says there is no such thing as consistency in real life. There is, however, such a thing as a constant-cause system. The results produced by a constant cause system vary, and in fact may vary over a wide band or a narrow band. They vary, but they exhibit an important feature called stability.

Why should anyone apply the terms constant and stability to a cause system that produces results that vary? Because the same percentage of these varying results continue to fall between any given pair of limits hour after hour, day after day, so long as the constant cause system continues to operate. It is the distribution of results that is constant and stable. When a manufacturing process behaves like a constant cause system, producing inspection results that exhibit stability, it is said to be in statistical control. The control chart will tell whether or not the process is in statistical control.

Scientific data are not collected for museum purposes. Rather they are used as a basis for doing something, otherwise why collect the data. The intermediate between the collection of data and the action is evaluation and prediction. The ultimate object in the use of statistics is to detect trouble and to provide a basis for action.

Control departments are faced with many difficulties and problems and have to contend with objectionable variations in temperature, strength of solutions, chemical mixes, replenishments rates, operating speeds among the many others.

If one drew up a chart of possible reasons for changes, he would find that a new one would present itself every day. It is only the mathematics of probability that can take into account these many factors. The probabilities are chosen on the basis of control knowledge, experience and clear thinking.

Since variability in processing must be recognized as a natural characteristic, the object of a control department is to compile all factors which arise and which are revealed by statistical computations. A particular study must also be made of the inherent variations in every process.

Quality control procedures establish the proper setting of processing conditions and automatically determine control limits which serve as warnings when action must be taken to prevent poor work. The control limits are set to improve quality, increase uniformity, prevent or reduce the production of unsatisfactory work—and the control charts provide a running record on the performance of equipment and personnel.

Use of Sensitometric Strips

Sensitometric strips are commonly used for color processing control. After processing the strips and reading specific steps on a densitometer, a collection of figures is provided which represent the color densities of the steps which were read. These figures are plotted on a graph. Over a period of time the densities will vary at random above and below a mean value despite the fact that no changes occur in the processing conditions. If after 20 or more plots one finds that a test varies from the mean by more than twice the standard deviation, the variation was not a random one. The test shows that the process is out of control and that a specific cause is assignable to this change.

For example: during a time when no changes were made in the processing conditions and more than twenty tests were made, two statistical calculations were made. The average density of a particular step on the sensitometric control strip was 1.805, and the standard deviation was 0.027. The control limits had been set at a probability level of approximately 95%; that is, at twice the standard deviation. If the processing is under control, no test should vary from the mean 1.805 by more than two times the standard deviation 0.027. The control limits are then set at 1.86 and 1.75 and if any test falls outside these limits one can say with an assurance of being right 95% of the time that the system is out of control.

At this point it is important to make the distinction between the processing being out of control or outside the acceptable tolerance limits. The occasion may arise when the mean of the processing is within the acceptable tolerance limits but close to the upper or lower limit. In such a case, unless the variance of the processing is very small, (although our processing may be actually in control) part of the production may be outside the accepted limits for good processing.

The control department's aim is to have both upper and lower control limits fall within the acceptable tolerances for good processing with the mean centered on or near the ultimate. It can happen that while the mean of the processing is centered between the upper and lower

* Berkey Photo Service, 77 East 13th Street, New York 3, New York.
Received 2 April, 1956. To be presented at Color Processing Conference sponsored by The Technical Division of the PSA in Rochester, New York, 25 and 26 May, 1956.

acceptable limits, and all points fall within the upper and lower control limits, still the control limits are outside the acceptable tolerance. In other words, the process is in control, but a certain percentage of work may not be acceptable.

Changing Standards

Another statistical aspect of color processing control presents itself when one is about to start on a new series or different emulsion number for the control strips. At such a time it is prudent to determine by test if the speed, color balance and such characteristics of the old and new series are so similar that they may be regarded as the same.

To make this test a number of the old and new strips are processed together under the same conditions and the means of the sensitometric characteristics under comparison are calculated. Then a test is made to see if the mean of the old set is significantly different from the mean of the new—or if there is a good possibility that both sets can be considered as having come from the same population. To do this, estimates of the variances of the two sets are pooled and "t" is computed for the difference between the two means using the following formulae:

$$\sigma^2 = \frac{\left[\Sigma(x_1^2) - \frac{(\Sigma(x_1))^2}{n_1} + \Sigma(x_2^2) - \frac{(\Sigma(x_2))^2}{n_2}\right]}{n_1 + n_2 - 2}$$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sigma} \sqrt{\frac{n_1 \times n_2}{n_1 - n_2}}$$

In such a test the mean speed of four old strips was 6.5 and the mean speed of six new strips was 9.0. The estimate of the combined variances of the two sets was 4.88, and the calculated value for "t" equaled 1.83 with 8 degrees of freedom. At a 95% probability level "t" is given in the tables as 2.31. Therefore, since the calculated "t" is less than the tabulated one there is no conclusive evidence that the old and new strips came from different populations, or were not the same. A further examination of the "t" table shows that this great difference between the means can occur one out of ten times.

In evaluating the results of a test run where the processing has been done under two different conditions, such as two different temperature controls or methods of replenishment, or types of agitation, one frequently wishes to know with some assurance whether the random variations of one of the two sets of control strips is significantly greater than the other.

For example: two sets of ten strips are processed with agitation A and two sets with agitation B. To learn if the variance of A is greater than the variance of B, one calculates the variance of each and the ratio of the variances, F.

variance A equals .498 with 19 degrees of freedom
variance B equals .354 with 19 degrees of freedom
F equals A/B or 1.41

The tabulated value of F with 20 degrees of freedom in both numerator and denominator is 2.15. If the calculated F is less than the tabulated value for the probability level chosen, generally 95%, then the hypothesis that there is no significant difference between the uniformity of processing is upheld. The F tables give the greatest value that can occur at a particular probability level by chance alone. Since the computed value of F is smaller than the tabulated one, one can assume that the variance due to agitation A, i.e., the uniformity of processing, is not different from B. More data might show otherwise; however, considerably more strips and continued testing would be required to prove it.

One of the greatest values in using statistics in color processing control is to be able to decide on one course of action or another and to know at least what the chances are for error if a wrong decision is made.

In analyzing a developer for bromide one might have the choice of two different methods of analysis and be undecided as to which appeared best to use. Again one may want to have some assurance that one method (perhaps it is quicker and less complicated) will not give incorrect results.

One can set up the hypothesis that the average difference between the two methods will equal zero. A number of analyses are made on different samples of developer using the two methods. The average difference between the two methods is calculated and the standard deviation of the difference and then a value for "t" is computed.

In a series of such tests the mean of the differences was −.07 with an expected value of zero. The standard deviation for the differences equalled .00186 and the computed "t" equalled 3.75. Since the calculated "t" is larger than the tabulated value "t" of 2.26, then there exists a 95% assurance that the expected value of a zero difference between the methods is wrong and there is a significant difference between the methods.

Analysis of Make-overs

The control supervisor has the problem of how best to handle make-over statistics and get the greatest good from them. One of the most useful procedures is to plot the grand average for all the printers each day. One can use the same techniques and procedures used for the fraction defective control charts in other fields. After plotting the make-over percentages each day for about one month, compute the mean and calculate for each day the control limits. Now one has a graphic picture of what happened, a record for management and a powerful tool for control.

Is the printing under control with random variations inside established control limits to which one can assign no specific cause, or do the plots fall one day above the control limits and below the next, each out of control? One of the great values of these charts is to guide production as to when a process should be left alone and conversely when to look for assignable causes such as mechanical difficulties in processing, or printing machines or operators' mistakes.

Conclusion: When properly applied, with an understanding of the fundamentals, statistics can provide a powerful tool for both management and production. One of the most useful rewards it can bring about is the understanding that in any process random variations

must be expected. One can, through a study of these random variations, post limits and know at any selected probability level when to look for trouble and when to leave a process alone. In addition, statistics can give the greatest amount of useful information from the test data.

Statistics properly applied to a color processing operation will give a laboratory the necessary assurances that the public will receive an end product which is the ultimate in color rendition from the film used and that the operation in total cannot fail to be a profitable one.

Bibliography

"Statistical Methods for Chemists," W. J. Youden, Wiley
"Industrial Experimentation," K. A. Brownlee, Chem. Pub. Co.
"Statistical Quality Control," E. L. Grant, McGraw-Hill
"Industrial Statistics," Wm. Volk, Chemical Engineering, Mar. '56

EQUIPMENT FOR MOUNTING COLOR SLIDES

Eugene G. Seary*

ABSTRACT

Slide mounts, heat sealers and film cutters have been developed for the semi-automatic mounting of 35mm color transparencies. One press and one cutter are described in detail, including provision for sequence numbering and edge notching to serve as "thumb marking."

The introduction of Kodachrome color film in 1937 introduced a new size in the slide projection field—the 2 × 2 inch slide with a 24 × 36mm opening. It also brought about the first large scale use of slide mounts, more particularly, cardboard slide mounts. This was a significant development for it contributed in no small way to the phenomenal success of reversible color photography with still film.

In 1937 the great popularity of 35mm black and white still photography had begun to wane. Color photography reversed this trend in very dramatic fashion. What is not usually realized, however, is that the new color transparency film minimized most of the very serious mechanical faults of 35mm black-and-white photographs. The virtual elimination of fingerprints, scratches, abrasions and dirt made color not only attractive but practical as well. The slide mount was, of course, responsible to a large extent for this preservation of the original quality after the developed film reached the hands of the consumer. The other advantages of slide mounts, such as convenience, storage, etc., are somewhat secondary to the function of protecting the transparency.

The first requisite for mounting transparencies is, of course, slide mounts. Thus far the only practical mount material for the color film finisher has been cardboard. This material, in the form of a scored but unfolded card with a heat sealing adhesive, has been most successful. Literally billions of slides have been prepared by color finishers, large and small, using this material. They are recommended, used, and sold by film manufacturers.

A slide mount, despite its low cost, actually is a precision product. All dimensions should be held ±.005 inch; some dimensions much closer. This precision, for paper products, is unusual. The depth of the score line is especially critical. Paradoxically the higher the

Fig. 1. Slide mount automatic sealing press for 2 × 2 inch and stereo slides. (Model II)

* Seary Manufacturing Co., 19 Nebraska Avenue, Endicott, New York. To be presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York, 25 and 26 May, 1956. Received 2 April, 1956.

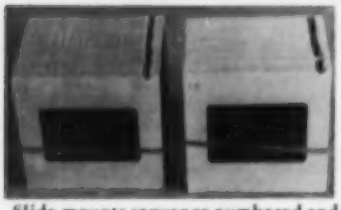


Fig. 2. Slide mounts sequence numbered and notched. The stack of slides on the right shows at a glance one slide out of position.

quality of the paperboard the more exact the score must be. The tolerance with a good hard stock is less than .001 inch.

The Heat Sealing Problem

Another difficult requirement to meet in order to make a good slide is a quick, reliable, and durable heat seal. The thickness of a slide mount makes the penetration of heat from side to side a slow process. The temperature of the sealing instrument is severely limited by the presence of heat susceptible film and by the charable nature of the paper itself. Therefore, an adhesive with the lowest possible melting point must be used in order to heat-seal the slide in a reasonable time. Very low melting point materials were found to have poor shelf life and ageing characteristics. Suitable heat-seal materials have to be controlled, therefore, within very narrow limits. With too high a melting point the slide can't be sealed in a reasonable time. With too low a melting point the slides are apt to block solid on the shelf before sealing, or fall apart after sealing. Experience showed very soon that adhesive on *both* surfaces to be joined yielded a tremendous improvement in heat sealing efficiency and reliability.

The application of adhesive to both inside surfaces of a slide mount of conventional construction is not very practical. A radically different type of construction was developed, therefore, to permit coating with adhesive both of the surfaces to be joined. This innovation was the now familiar dimpled film retainer. By applying adhesive to the blank before punching, it is possible to have both surfaces coated. It was soon noted that registration of the film by means of dimples is more positive and far more accurate than was the case when conventional registration means were employed. The elimination of the conventional nest also results in a remarkable reduction in the tendency for a transparency to "pop" when exposed in a projector using a high wattage lamp.

The Sealing Press

Having obtained suitable slide mounts, the next problem of the color finisher is to seal them with the film inside. A number of devices have been developed for this purpose. The simplest of these are manually operated presses which were offered by Ansco and by Pentagon Products. Manufacture of both these presses has been discontinued. A rather elaborate device is the one built by the Eastman Kodak Company, originally, for their own use, and recently made available to color finishers. Between these two extremes, four power-operated presses have made their appearance. One of these is offered by Heat Sealer Company of Los Angeles, the second by the Eastman Kodak Company, the third by Pako, and the fourth one by Seary Manufacturing company of Endicott, New York. The latter is shown in Figure 1.

This is the Seary Model II, for 2 × 2 inch and Stereo slides. A larger machine, Model III, is made for $2^{3}/_{4} \times 2^{3}/_{4}$ inch size mounts for roll film color pictures.

The press itself is automatic but the entire process of slide mounting with this press is considered semi-automatic. A mount and a transparency must be assembled by hand before insertion in the press. From that point on, mounting is automatic. When the assembled slide is put into the press, the press closes automatically as the slide reaches the proper position. After an electrically timed dwell, the press opens by itself and the sealed slide drops down a chute and into a neat pile in the bin. The proper heat is maintained by a thermostat and the entire unit is electrically operated and portable. Approximately 20 film rolls of 20 exposures each can be sealed per hour with this press, using recommended mounts.

The platens which actually touch the mount to accomplish the sealing are easily removed. Interchangeable platens are available to seal stereo slides and the "Super Rollei" slide. The change-over can be accomplished in less than 3 minutes.

In addition to the above mentioned attachments, two other accessories can be added; a sequence numbering device and a notcher. The numbering device stamps numbers consecutively from 1 to 24 in the upper left corner. A dial is manually set at "one" at the start of each roll of film. The rest of the numbering operation is entirely automatic, but the transparancies must be kept in order. Keeping transparancies in proper sequence is best accomplished with a cutter which is described later.

Notching is a most convenient method of orienting slides for projection. The Seary notching attachment places a small semicircular gap in the upper edge of the

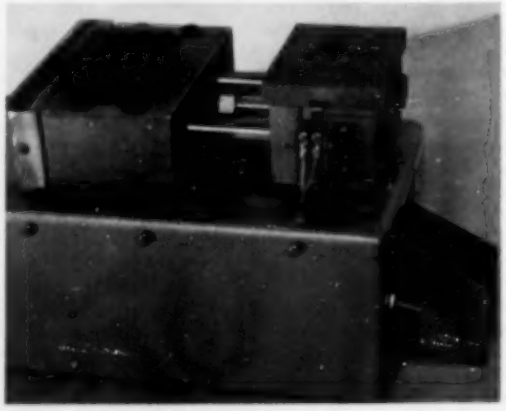


Fig. 3. Seary Model II heat sealing press with covers removed showing magnet, slide rods, push rod and press blocks.

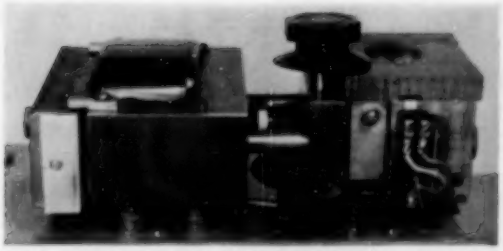


Fig. 4. Press with numberer and notcher. Note the extra sliding block to carry the numberer shaft and notching punch.

slide, near the right hand corner. Thus even in the dark the projectionist can instantly tell which way to insert the slide into his projector. The notch also makes it possible to quickly arrange and entire stack of slides for mistake-free projection. A glance is all that is required to check on every slide in a pack. Figure 2 shows the sequence number and the notch and indicates how a stack of properly oriented slides appears.

Mechanical and Electrical Features

The foregoing tells what the sealing press will do. How it is done is a rather simple mechanical and electrical story. Essentially, the press consists of 2 metal platens, one of which is heated. An electromagnet is used to force the platens together causing a slide between them to be heat sealed. Figure 3 shows the press with covers removed. The platens are carried by the two heavy blocks near the front. These are held in place and connected to the magnet by two slide rods. These rods and the center push rod take the entire stress of the pressing force. No stress is transmitted to the press frame. This eliminates all flexing usually found in "C" type construction and permits the machine to be built much less massively.

The electro magnet is of conventional "E" type, but should not be confused with solenoids. The core and armature, contrary to the usual practice in inductive devices, are not laminated. The construction was designed to provide the strongest possible structure. The press exerts approximately 1000 pounds pressure so the mechanical strength of the parts must be adequate. Solid cores yield slightly sluggish magnets but for a slide-sealing press this is an advantage. When the magnet coil is energized, the armature is drawn toward the core, pushing the bronze rod which in turn pushes the sliding platen block.

The total movement necessary in a slide sealing press is only about .045 inch. It has been possible, therefore, to use a directly connected magnetic device as a power source in spite of the fact that the strength of a magnet drops off rapidly as the armature recedes from the main core. The gap of the press is normally adjusted for .090 inch. A quick way to check this is to fold two slide mounts and insert both together into the gap. The press is adjusted till the mounts fit snugly. Adjustment is effected by turning the nuts on the brass push rod. For maximum pressure on the slide, the armature should be within about .005 inch of the core when pressing. There is no adjustment for armature spacing on the standard press, it having been found that all available slide mounts at present are within .004 inch in thickness. The later model presses with numberers or notchers have an adjustment for armature spacing, however, and this is accomplished by an extra nut and locknut located on the front end of the brass push rod.

The .090 inch platen gap mentioned above has been found to be narrow enough to prevent film from falling out of position in the mount. At the same time, this gap is wide enough to permit the slide to drop freely out of the press after sealing when the platens open. The mount with the film in position must be grasped firmly in the fingers to prevent the film from losing register with the aperture. After the mount has entered the gap of the press about $^1/_2$ inch, there is no further danger of the film slipping.

As the slide is fed into the top of the press, a microswitch is actuated. (This is effected by having the switch lever extend into the slide path just above the platens.) While the switch is in this position, the timer capacitor is charged. When the slide reaches pressing position between the platens, the switch lever can return to its normal place and this starts the pressing operation. The timer consists essentially of a relay, a rectifier, a capacitor and an adjustable bleed resistor much as in an electronic timer. No vacuum tubes are used, however, since a high resistance coil in the relay permits adequate dwells with a reasonably sized capacitor. The usual rectifier protecting resistor and arc supressing capacitor are used.

A temperature of about 250 F is maintained with a 125 watt resistance heater controlled by a snap action thermostat. Mounts can be sealed with a temperature as low as 180 or even lower, but the adhesion is un-reliable at lower temperatures and the pressing time excessive. If a normal dwell of $1^1/_2$ to 2 seconds is to be maintained, the temperature should not be less than 220 F.

Figure 4 shows a press with the numbering device and notcher installed. These devices require an extra sliding block to carry the numbering wheel and punch. The two sliding blocks and rear platen are slotted to permit the numbering wheel to contact the slide as it is held between the platens. When the notcher is installed it is necessary to dowel the platens in place and build the entire assembly to die set accurately. With either the numbering attachment or the notcher, it is not practical to have interchangable platens so the press becomes a one purpose machine. A magnetic ratcheting device indexes the numbering wheel, advancing the wheel $^1/_{24}$ revolution every time the press closes. The wheel embosses the number into the paper mount, the force being supplied by the press action itself. A little ink is applied to the numbering wheel as it rotates past a spring loaded felt inking disc. A very small amount of ink makes the embossed number much more legible. Stamp pad inks and postage meter inks on the inking felt work very well. The numbering wheel has raised letters engraved on its peripheral surface, and is hardened to resist the well known abrasive action of paper.

Both the main magnet and the numberer magnet are operated by direct current. A conventional half wave rectifier with smoothing capacitor are used to provide this power. A 500 ma rectifier is ample for the job. Considering the force produced by the main magnet, the current required seems remarkably low, about 200 ma, or 20 watts.

In both numbering and notching somewhat more care must be exercised in mounting than is the case for plain slides. The film must be placed in the mount with a definite relationship as to emulsion side. Also the bottom of the picture must always be *down* in the press, whether the picture is a horizontal or a vertical view. A great aid in matching the transparency to the mount is a 35mm film cutter such as the Seary Model II shown in Figure 5. With this machine, never more than one piece of loose film is on hand at one time. Each transparency is mounted immediately after cutting. This eliminates all confusion as to sequence and emulsion side and makes identification of vertical versus horizontal quite easy. A great reduction in dirt and scratching also results from handling film this way. Best of all from a production point of view is that nearly 50% more slides can be sealed.

Transparency Frame Cutter

The cutter was originally designed to cut film for stereo pairs, which it still does. The conversion from 2 × 2 inch slides to stereo pairs is accomplished by merely throwing a toggle switch. The cutting of stereo film is normally a very time consuming operation because of the accuracy required. Fortunately, all stereo cameras on the market at present keep register between picture and film perforations. The cutter advances the film exactly 5 perforations for every cut. It is possible to automatically feed an entire roll of stereo film with a high degree of precision. It has been found, in fact, that the film sealed into Seary stereo mounts is successfully projected. Again as in 2 × 2 inch slide work the great virtue of the machine is quality coupled with efficiency. Thirteen stereo rolls per hour per operator is not uncommon.

Figure 6 shows the indexing mechanism of the cutter. It can be seen that machine tool techniques are used.

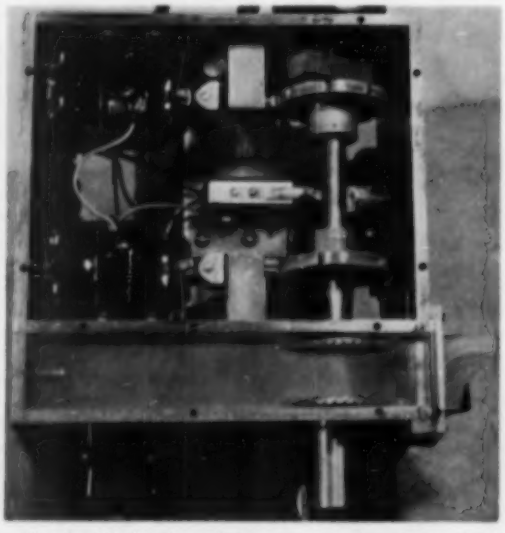


Fig. 6. Mechanism of 35mm cutter—showing method of withdrawing pawls from indexing heads.

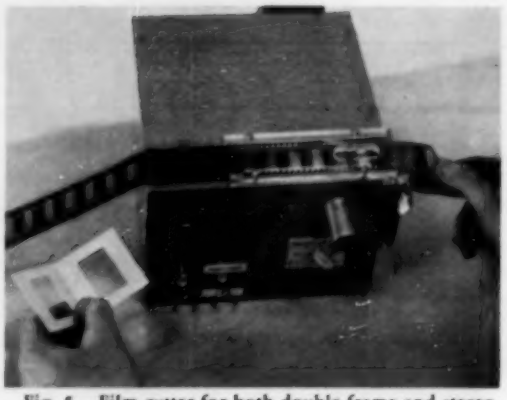


Fig. 5. Film cutter for both double frame and stereo. Automatic advance for all stereo pictures and about 90% of all double frame films is possible with this machine.

This was made necessary by the great accuracy required for stereo cutting. The indexing heads and sprocket are very accurately machined. Indexing heads and pawls are hardened to maintain original accuracy.

When the actuating button is pressed, the knife solenoid is energized. The solenoid moves a lever connected to the knife, and the film is severed. Interlock switches make the knife solenoid inoperative while the sprocket shaft is rotating. Thus transparencies cannot be cut in two by inadvertently pushing the actuator button while the film is being advanced. As the knife returns to its original position after making a cut, a switch is actuated which in turn energizes a pawl solenoid. As the pawl pulls out of the indexing head slot, another switch is actuated which starts the motor. The solenoid is then de-energized and the pawl is released and rides on the outer surface of the indexing head until it drops into the next slot. The motor is then shut off by the switch connected to the pawl. A time delay circuit is employed to prolong the pawl solenoid energization to ensure the motor starting and running long enough to prevent the pawl from dropping back into the original indexing head slot. The motor is dynamically braked to reduce wear and tear on motor coupling, gears and pawls.

Continuous energization of a pawl solenoid renders one of the pawls inoperative. The changeover switch selects one or the other pawl solenoid to be continuously energized. One indexing head has 5 slots, the other 8. These, working with the 40 tooth sprocket, allow either an 8 or 5 perforation hole advance of the film.

The year 1956 undoubtedly will see a great increase in the use of color rollfilm. The availability of high speed Anscochrome and Ektachrome films makes possible for the first time the use by amateurs of reversible color material in a box camera. The high quality and relatively low cost of *reversible* color pictures is bound to attract the box camera owner. To put color rollfilm in the hands of the consumer in a practical form is highly desirable and slide mounts seem to be the answer. It has been found that rollfilm can be handled exactly like 35mm miniature camera film in spite of the large area envolved. Mounts and sealing presses are available and are nearly identical, except for size.

THE IMPORTANCE OF ACCURACY IN STEREO MOUNTING

J. L. Simpson*

Stereo specialists, consultants, technicians, and "dedicated enthusiasts" have long been talking and writing about the importance of correct and accurate mounting of stereo films, not only for projection but also in the interest of greater eye comfort in hand viewing.

Careful and painstaking studies in the field of stereo, conducted among groups composed both of neophytes and those who are aware of the problems, indicate that the misplacement and misalignment of stereo pairs by a mere few thousandths of an inch reduces "acceptance" of stereo by both the trained and untrained eyes. When such misalignment reaches as much as 25/1000ths of an inch—and this amount is almost ordinary in some mounting materials—the eye and brain acceptance of stereo falls away almost to the vanishing point.

In hand viewing a person with normal eyesight can accustom and adjust his eyes to misalignment quite readily, though it usually takes a bit of blinking and second or third looks through the eye pieces of the viewer to do this. When it comes to projection, however, misalignment can only be taken care of by adjustment of the projection lenses to balance either vertical or horizontal alignment. There is no adjustment possible, however, when one or both stereo films are not in square alignment with one another.

An easy-to-use and practically foolproof method of mounting stereo pairs is the metal double-fold mask (see Figure 1) which provides die cut nibs for holding the corners of the films. No adhesives or sealants are used. The nibs are so designed that only enough tolerances are provided for easy slippage of films under the nibs, and to take care of film expansion under varying weather and climate conditions. This allowance is exactly 2/1000ths of an inch vertical and horizontal. In mounting by this system, only careless or incorrect cutting of the films can cause trouble, which can be corrected by trimming of film to square it properly.

Choice of Masks

When films are cut properly, the user need only to watch carefully the proper choice of mask. Masks are provided in Normal, Medium, or Close-Up, with these designations imprinted in the metal just below the manufacturer's trademark on the back, or lower half, of the mask.

The Normal mask is used for films when the near point of subject matter is over 7 feet from the camera taking lens and the far point is over 20 feet. The stereo window is set at 7 feet.

The Medium mask is used if near point is from 4 to 7 feet, and far point is not more than 20 feet, with stereo window set at 4 feet.

The Close-Up mask is used if near point is from $2^1/_2$ to 4 feet, far point not over 7 feet, with stereo window set at $2^1/_2$ feet. When the proper mask is chosen and used, hand viewing of the mounted stereo pair is much more comfortable, and in projection adjustments of lenses are entirely eliminated with no discomfort to the viewing audience.

If the camera was not level when the picture was taken, of course, one film will appear higher or lower than the other when mounted. This situation can be detected readily in the viewer, before the mask has been folded. For accurate projection it is then necessary to trim either the top or the bottom of one film to bring it into alignment, and the film nibs creased tightly onto the film edge to hold it firmly.

By this system mounting is accomplished directly from the cutter to the mask. Starting from the front end of the roll, the first picture cut is the first Right picture, which goes under the Right nibs of the mask. The next frame is blank. The third frame is the second Right, and goes under the Right nibs of another mask. The fourth frame cut is the first Left picture, and is placed opposite the Right picture in the first mask used. This mask is finished, examined in the viewer, and folded. The fifth frame cut is the third Right picture, and it is placed under the nibs of another mask—and so on through the roll, with the films being handled only once—from cutter to mask.

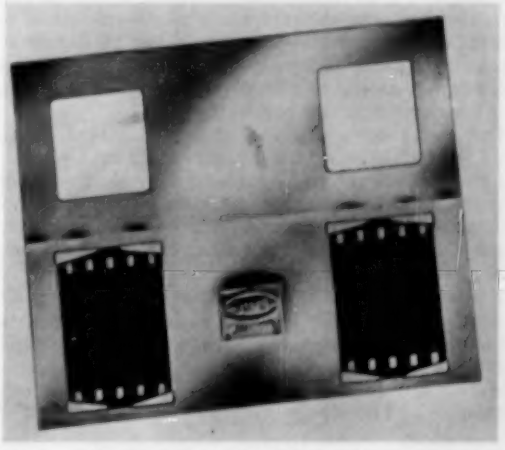


Fig. 1. Aluminum mask with die cut corner receptacles for accurately positioning the stereo pairs.

* EMDE Products, Incorporated, 2040 Stoner Avenue, Los Angeles 25, California. To be presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York, 25 and 26 May, 1956. Received 29 March, 1956.

Other advantages of metal masks are: maximum protection against the formation of Newton's rings and avoidance of film buckling, because of the air space of 5/1000ths of an inch on both sides of film when it is under glass; freedom from dust, lint, paper flecks so noticeable in stereo films; knife-sharp window edges and freedom from ragged aperature edges. In addition to mounts for American Standard stereo pictures, the aluminum frames are available for mounting single frame transparencies in the 2 × 2, $2^3/_4$ + $2^3/_4$ and $3^1/_4$ × 4 inch sizes for slide projection.

For mounting of films under glass, a one-piece aluminum frame is provided (See Figure 2) to hold the glass-mask sandwich, which is merely slipped into the open end of the frame, and the lip of the frame folded over when the assembly is in place. Mounting under glass is strongly advised for projection; also for protection against fingerprints, scratches, and smudges.

For users not wishing to mount under glass, a simple mask frame is provided, into which the folded mask is slipped, with no adhesives or sealants.

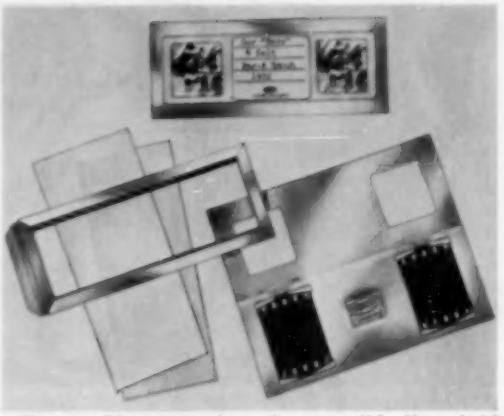


Fig. 2. Glass mounting of stereo slide films, held in the aluminum fold-over mask, is accomplished by sandwiching between glass plates and sliding the assembly into a pre-formed aluminum frame.

A SLIDE-RULE FOR PERCENTAGE MASKING AND GAMMA DETERMINATION IN COLOR REPRODUCTION WORK

Robert R. Erwin*

In color reproduction work, where principal masking is employed to correct separation negatives and positives, various methods are used to compute the ranges of masks to be made to certain percentages of the range of the original color transparency. Some forms of tables are published, and the percentage of a mask can be calculated on a conventional slide-rule, but by the use of a specially adapted slide-rule the readings can be made quite easily, as the rule incorporates only the numbers used for that particular purpose.

The reader will quickly see that the slide-rule (Figure one) is the ordinary logarithmic slide-rule up-ended, the numbers set at a right-angle to their usual positions, and graduated in the values common to the logarithmic densities used in sensitometry. The right- and left-hand scales are in fixed position, and the center scale slides between them.

To use an example; assume a color transparency at hand to be separated by the indirect method for reproduction by one of the four-color printing processes. Using a densitometer to read the densities of the transparency, a reading is obtained of 2.8 in the shadows, and .4 in the highlights. The range of the transparency is 2.4 (highlight density subtracted from shadow density). If one of the masks is to be made to 30 percent of the range of the original, the center movable portion of the scale is positioned so that the number "30" of the right-

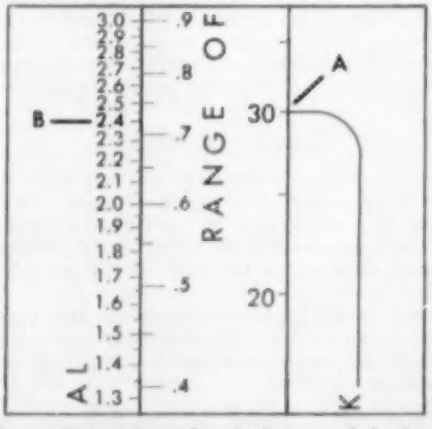


Fig. 2. Using the slide rule for a mask having 30 percent of the range of the original, the number 30 is lined up at point A.

* 165 Woodbury Avenue, Springdale, Connecticut. Received 3 February, 1956.

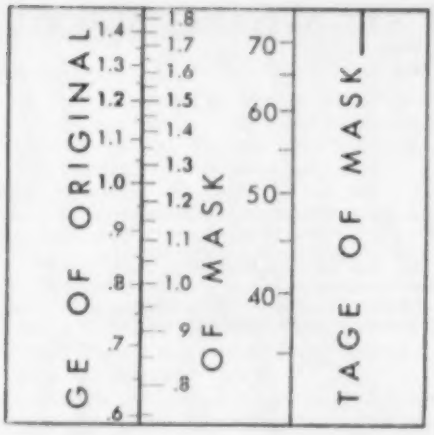


Fig. 3. For determination of gamma, the slide rule is adjusted so that the "Range of Mask" density is lined up with the "Range of Original" density and the development gamma read on the center scale opposite the 1.0 mark of the "Range of Original" scale.

hand side of the center scale is opposite the index mark on the right-hand section marked PERCENTAGE OF MASK, as illustrated in (a) of Figure two. The desired RANGE OF MASK is read opposite 2.4 of the RANGE OF ORIGINAL scale as approximately .72 (as shown at (b) of Figure two). Exposing and developing the mask so that the densities read from 1.12 to .40, it will be found that the range of the mask is .72, or 30 per cent of the range of the color transparency.

The same method is used for subsequent computations in finding ranges for additional masks used at different percentages. Variations of use will be apparent; the percentage of a mask can be ascertained by positioning the RANGE OF MASK reading opposite RANGE OF ORIGINAL and reading the percentage indicated by the index mark on PERCENTAGE OF MASK. The gamma of a negative or positive can be read by setting the RANGE OF MASK density in line with the RANGE OF ORIGINAL density, and the development gamma read on the RANGE OF MASK scale opposite the 1.0 mark of the RANGE OF ORIGINAL scale. Thus, a positive that has a range of 1.5, made from a negative whose range was 1.2, was developed to a gamma of 1.25 (see Figure three).

In making the slide-rule easy to read, some details must be sacrificed. A value such as .78 can only be estimated by judging its position between .75 and .8.

Readers of PHOTOGRAPHIC SCIENCE AND TECHNIQUE may copy the scale for their own use. However, in the process of reproduction and printing, the scales may stretch or shrink enough to throw them out of coincidence. This will not do too much harm, but if the user is concerned with that effect, he must copy the main illustration on a process camera, making sure that the plateholder and copy board are parallel. Prints should be made on a water-resistant base paper, preferably cemented to thin metal before printing and processing. Correction of the graduations can be made by comparing the resulting scales with the appropriate section of an accurate two-cycle logarithmic scale.

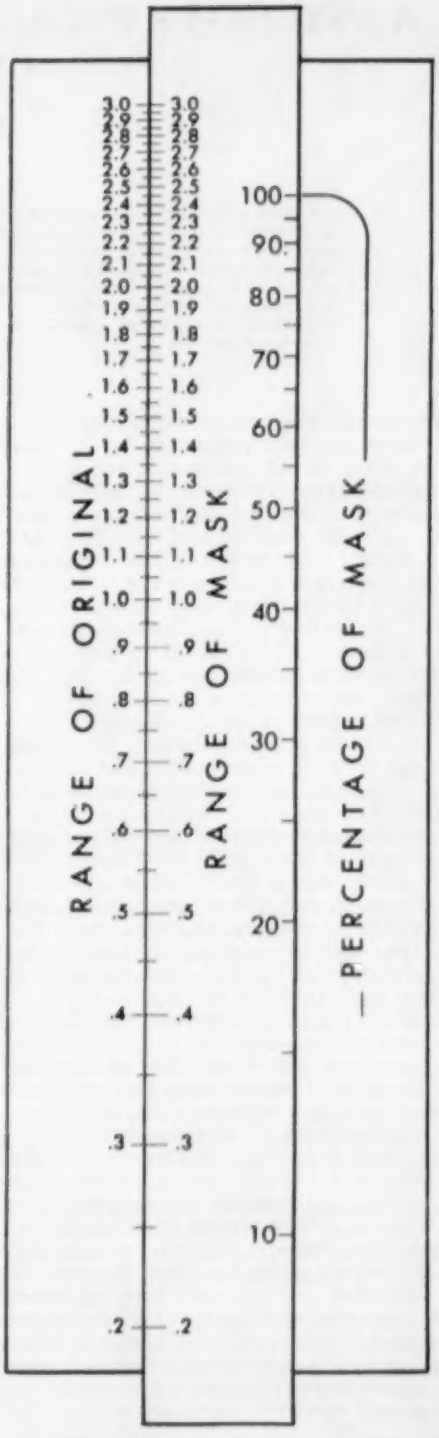


Fig. 1. Slide rule for rapid determination of range of mask for correcting color separations.

A PSYCHO-PHYSICAL STUDY OF STEREO SLIDE ALIGNMENT

M. R. Goff*

ABSTRACT

A group of fifty-one people rated stereo slides for visual comfort in a stereoscope. A precision mechanism permitted one transparency of each pair to be moved vertically or rotated known amounts with respect to the other. Many random settings of each slide were judged by each person. Examination of individual preferences showed how consistent each observer was, how much displacement he could tolerate and features relating to the normality of his vision. Study of average preferences gave information on whether experience, fatigue, type of slide, and viewing sequences affected viewing comfort. This information is presented in a series of graphs, and some of the implications to the individual and to industry are discussed.

One of the major factors which influence an observer's acceptance of a stereo slide is the amount by which an image on one transparency is displaced vertically with respect to its homologous image on the other transparency.[1] Horizontal displacement is much less critical. One not familiar with this fact can easily convince himself of its validity by first cutting a standard cardboard stereo mount in two halves, along a vertical center line. By removing, say, $^1/_8$-inch of material parallel to the cut line, and re-assembling the slide with the two transparencies $^1/_8$ inch closer together, it can be shown that comfortable viewing has been retained. If, however, the two halves are re-assembled with a vertical displacement of one transparency with respect to the other of $^1/_8$ inch (i.e., bottom line of one half-mount that distance below bottom line of other half-mount), the average observer will be unable to fuse the picture in a hand viewer.

As vertical misalignment increases from zero, viewing comfort decreases until, as in our example, a normal observer finally sees a double image. Camera, film, filters, mounting, and viewer can all contribute to this misalignment. In addition, imperfect vision may alter an observer's range of acceptable alignment by introducing subjective errors.[2,3] The work described in this paper is a basic study of the dependence of observer acceptance on vertical misalignment, regardless of cause, and for hand-held viewing only.

The continuing growth of color photography constantly brings new organizations into the business of processing and mounting transparencies. This brings the difficult problems of mounting stereo color transparencies to photofinishers who have never before had to consider such factors. Manufacturers of cameras, filters, close-up attachments and viewers, as well as those who provide mounting services, should fully appreciate the narrow tolerance in vertical alignment which the average person has; how far from average a single individual can be; and how equipment and services other than their own can affect acceptance of their product. Perhaps such a quantitative understanding can lead to agreement through standards association action on tolerance limits for each product. In the absence of such standards, a manufacturer needs information upon which to base his decision as to how complete his line of equipment and services should be: (i.e., how many of the possible variables he should keep under his own control).

An individual owner of stereo equipment and slides, especially if he does his own mounting, may wish to apply some of the information given here to his personal problems.

Alignment Factors in Stereo Photographs

1. Camera, Filters, etc.

The two apertures† of a stereo camera must be correctly separated and correctly aligned with respect to both the lenses and the film. Their horizontal spacing helps determine the position of the "window" and affects depth judgment to some extent.[4] The vertical positioning of the apertures, by itself, is unimportant if differences are of a low enough magnitude to be covered by the apertures of the mount. If the camera does not transport the film uniformly, frame lines may overlap and cause cutting difficulties. Those problems are outside the scope of this report. However, any situation in the camera which alters the distance of one or both homologous points from the film edges will be of concern because the film edge is a very practical reference line for stereo mounting work.

A condition of the camera which causes one lens to place its image above or below that of the other lens due to imperfect alignment of their optical axes is such a situation. Another is the wedge effect in filters. Still another involves the film advancing and position mechanism and the clearance between the film edges and the film guiding mechanism. Where there is appreciable clearance between film and guides, an advancing and positioning mechanism which pulls the film to one side will cause error by cocking it slightly. Imperfect positioning of auxiliary close-up lenses can cause very large errors.

By using well-defined images in any stereo pair and a traveling microscope type of measuring device, anyone to whom this information is necessary can find out how his own camera behaves in this respect. The degree to which his lens axes are aligned initially is controlled by

* Manufacturing Experiments Division, Eastman Kodak Company, Rochester 4, New York. Presented at the PSA National Convention in Boston, Massachusetts, 8 October, 1955. Received 16 March, 1956.

† Here the word aperture is used to denote the opening in the back of the camera (in its function of masking) which determines where the picture area will be.

cost of manufacture and quality control. Mishaps may later alter the alignment.

2. Mounting

Assume that the transparencies to be mounted have been produced in a perfect camera and that homologous points are at equal distances from the film edges. The effects which improper mounting can cause in a stereo pair may be briefly considered as follows. Figure 1 shows four types of misalignment. These types of misalignment can arise from causes other than poor mounting, but they can be explained most simply at this point.

Figure 1a shows what is called vertical translational misalignment or uniform "dipvergence." Every point, A_L, in the perfect stereo pair is higher than its homologous point, A_R, by the amount D. Center points, C, are no different from other points.

Figure 1b shows the simplest rotational case, in which only one transparency is rotated about its center, C_R. Here, with no accompanying vertical translational misalignment, the worst places are in the extreme corners of the transparency, as at A.

Figure 1c shows both transparencies rotated in the same direction. Each point is dropped or raised the same amount as its homologous point, even at the outermost corners visible, points A.

Figure 1d shows the effect of rotating the transparencies about their centers, C, in opposite directions. Here point A_L is raised in the left transparency and its homologous point, A_R, is lowered in the right transparency.

Variations of these types of misalignment are possible, including simultaneous rotation and translation. When rotation is added to translation, it causes less total misalignment than an equal amount of pure translation *if measured by greatest vertical difference between any two transparency corners*. This is true because points on one side of center are always rotated into *better* vertical alignment.

Anyone who mounts stereo slides without perfectly aligned reference surfaces against which the tops or bottoms of the transparencies can be rested while they are fixed in position must cope with this problem.

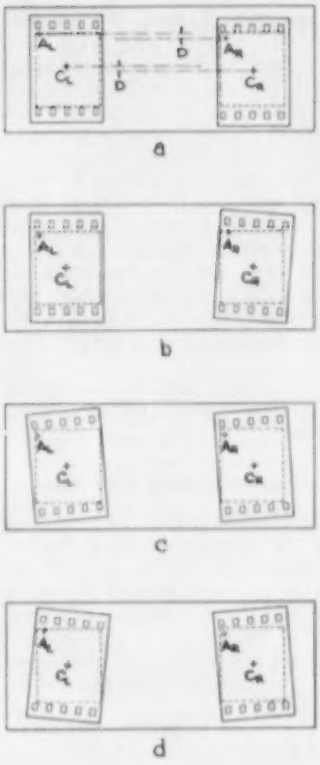


Fig. 1. Four types of misalignment of stereo pairs. (a) Vertical translational misalignment, (b) single rotation, (c) double rotation in same direction, (d) double rotation in opposite direction.

3. Viewer

One lens of a hand viewer may be not aligned properly with respect to the other lens and with the base against which the slide is aligned. In some viewers there are small projections which locate the bottom line of the slide. In other viewers the bottom line of the slide rests directly against the bottom of the slot which holds it. If the viewer has misalignment which makes the slide *appear* to be misaligned, the effect upon the observer is just as marked as is slide misalignment itself. This fact was recognized in the present work by making corrections for viewer misalignment. It is, of course, necessary for the slide to be seated correctly in the viewer.

If one places a shim under one end of the mount, he can simulate a viewer misalignment. (Likewise, a slide which has an undesirable amount of vertical misalignment can be corrected in large measure by filing its bottom in such a way as to bring images on the "high" transparency down to coincidence with images on the "low" transparency. A traveling microscope or a calibrated projector can be used to measure alignment. If a projector is used, neither horizontal nor vertical controls should be moved after the vertical alignment has been adjusted with the standard slide. In addition, the slide carrier must be set in the same way each time it is used.)

4. Observer

An observer who has sight in only one eye must make all of his depth judgments on the basis of monocular cues only. Stereo photography is unnecessary for him, because his judgments are based on factors such as the known size of objects and their appearance with distance, overlap, shadows, etc.

With binocular vision, there are still factors which limit the enjoyment of stereo photography. One of these is the possession of a vertical phoria. This defect is the tendency of one eye to turn up or down in relation to the other.*

Obviously, if an observer has a vertical phoria, he will find it easier to accept a stereo pair which is misaligned with one transparency low (in accord with his phoria) and more difficult to accept with the other transparency

* In technical language, the tendency of the right eye to deviate up in relation to the left eye is called a *right hyperphoria* or a *left hyperphoria*. These terms can be altered to describe the tendency of the left eye to deviate up in relation to the right eye: e.g., left hyperphoria.

low. The existence of these phorias will narrow the average range at a given very high level of percent acceptance. Some people will cut the range on the plus side, and some will cut it on the minus side of the misalignment scale, where observers with equal range but without vertical phorias would accept all settings.

Some observers are able to fuse images comfortably over a very wide range of alignment (both horizontal and vertical), even allowing their eyes to diverge. And, of course, there are wide differences in the consistency with which various observers form their judgments. It should be mentioned here that no consistent observers were found during these experiments whose range of acceptable misalignment was so small and whose vertical phorias were so large that a perfect setting was not comfortable.

A number of people had to be allowed to rate the slides to get a representative cross-section of our potential stereo customers.

Experimental Procedure

An ideal experiment to find out how stereo slide alignment affects the average person's comfort of viewing could be imagined to follow several different plans. Each would involve some way of presenting many slides with known and varying degrees of misalignment to a large group of people in a well-aligned stereoscope. There will be a limit to the number of slides each person can look at, both because of fatigue and because of testing time and cost.

The first plan tried in preliminary tests used a large number of different cardboard-mounted slides, deliberately misaligned to varying degrees. Consistent results were not secured in this experiment. Each scene was presented at only one or two different degrees of misalignment, so it was not possible to determine from the data whether inconsistency arose from differences in slides, in observer range, in observer consistency, or from other causes. The difficulty of producing just the degree of misalignment in each slide needed to get a complete set suitable for answering the questions raised caused this method to be abandoned in favor of the next plan tried.

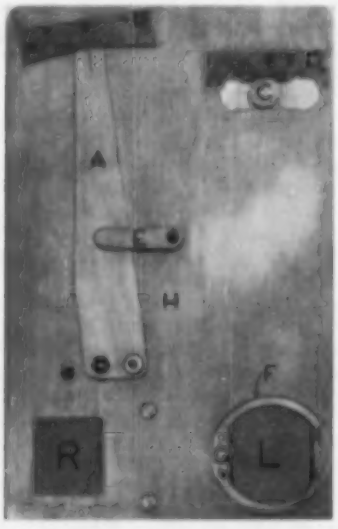


Fig. 2. Adjustments on stereo mount, not visible to the observer, which indicate the intentional misalignment of stereo pairs.

The second plan used a smaller number of stereo transparency pairs held in an adjustable mount. This mount could be adjusted quickly to give the transparencies of any pair a wide variety of misalignments. Since it could either raise or lower one transparency with respect to its mate, its use permitted a much more complete analysis of the data from a small number of precision measurements. This is the plan which will be described.

Since the exact method of administering an observer reaction test of this type is often vital to the results, complete experimental details will be given.

1. Adjustable Stereo Mount

The side of the adjustable stereo mount which was not visible to the observers who rated the slides is shown in Figure 2. The actual width of the mount is 4 inches, the same as that shown for the five perforation format mount in American Standard PH3.11-1953.

Movement of the lever, A, in Figure 2 to the left, lowers the observer's right-eye transparency, R. Movement of A to the right raises R. Each of the smallest divisions on the scale, B, represents 0.005 inch travel of R. With 44mm viewing lenses, this equals 10 minutes of vertical misalignment or of uniform dipvergence. The eight divisions, plus or minus, on B therefore represent 0.040 inch of travel of R. The next two (lighter) marks some distance to left or right of the scale represent an additional 0.020 inch of travel of R. The right-eye transparency can thus be moved either up or down 0.060 inch.

Movement of the lever, C, to left or right moves the observer's left-eye transparency, L, rotating it about its center. Movement of C to the left produces clockwise rotation, as seen by the observer. Movement to the right produces counter-clockwise rotation. The scale, D, is also set up so that each of its smallest divisions represents a change of 0.005 inch. Here one corner drops 0.0025 inch, and the opposite corner rises 0.0025 inch, transforming rotational motion into a similar translational equivalent. Scale D also shows 0.005 inch intervals, plus or minus, to 0.040 inch and then a 0.020 inch jump to 0.060 inch. In addition, the extreme limits of the scale are marked and represent ± 0.075 inch from the center.

The arm, E, introduces enough friction into the movement of A so that the right-eye transparency carriage (not shown) does not move under the force of gravity when slightly jarred. Enough friction was left in the circular seating surface, F, between the left-eye transparency carriage, G, and the stationary base, H, so that a similar arm is not needed on C.

2. Measurements on Viewer, Adjustable Stereo Mount and Individual Transparencies.

By using a double collimator furnished by the Hawk-Eye Works it was determined that the right lens of the hand viewer used in these experiments looked down

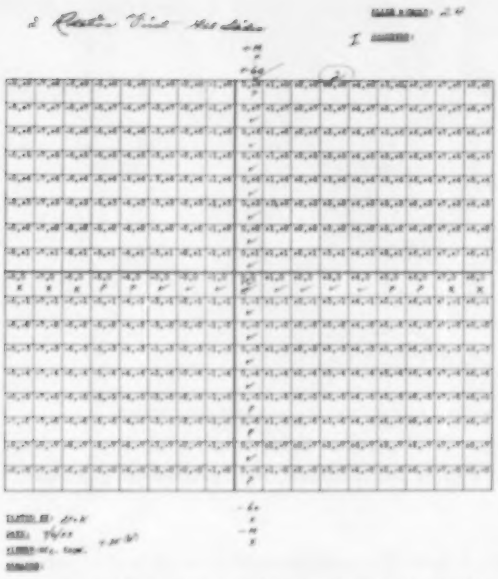


Fig. 3. Rating sheet used in conjunction with the adjustable stereo mount.

0.004 ± 0.001 inch, the slide with the best reference points giving a value of 0.005 inch.

Use of a traveling microscope type of instrument showed that the zero point of the translational scale of the adjustable stereo mount was within 0.001 inch of dead center, and that the 0.005 inch intervals marked on the scale and the total motion of ± 0.040 inch were correct to ± 0.0005 inch. The extreme positions of ± 0.060 inch were within ± 0.001 inch. The rotational scale was accepted as manufactured from the designer's calculations. The uncertainty in transparency seating was estimated to be of the order of 0.001 inch, maximum. Measurement on the eight slides used in the tests with the adjustable mount showed differences of homologous point distances from transparency bottoms ranging from 0.000 to 0.0035 inch. Infinity points were not available in all slides and even sharp points at moderate distances were unavailable in some of the 0 set of slides. There was the choice of using all sharp, easily measurable slides or of using the wider variety of slides originally planned, with some attendant loss in precision. The latter course was chosen and it was concluded that corrections for individual slide variations could not be made with an accuracy to warrant their employment. It will be seen that the method of use of the adjustable stereo mount is such that small errors will be minimized by averaging plus and minus settings.

Rapid scale settings to better than 0.001 inch were relatively easy, and all settings were approached from the right side to minimize any play which might develop in the mechanism during use.

The focal lengths of the lenses in the viewer used were measured and found to be between 44 and 45mm.

3. Rating Sheets

Figure 3 is one of the "raw" data sheets from the adjustable stereo mount rating tests. Four of these sheets were stapled together before a test. Each had the slide number in the upper right-hand corner, and the sheets were in the order in which the slides were to be shown to the observer. (The observer's name has been covered.) The number at the top left of the sheet is the observer's number. In this case he was the second person tested. Following his number is the rotational-translational sequence. Here all slides were shown first with variations in the rotational settings. Then they were shown in the same order with variations in the translational settings. The circled number under the observer's name denotes the order in which this slide was observed. This was the second slide viewed by this observer. The "I" before the observer denotes that this man was classified as an intermediate in stereo experience. The letter B was used to denote a beginner, and E, to denote an expert. At the bottom of the sheet are spaces for the initial of the tester, date, viewer used, and remarks. In most cases, times of each section of the test were recorded. They were not recorded completely in Figure 3, the single time showing only that the rating was done about mid-morning. The two checks in square 0,0 at the center are identified by the "T" for the translational portion of the rating and by an "R" for the rotational portion.

Each column of the data sheet represents variations in the rotational setting at a fixed translational setting. Marks in the column used, the O column, thus show the acceptance at no translational misalignment but at various rotational settings (as introduced by the adjustable stereo mount—any defect in the alignment of points in the picture with respect to the film edges or in the viewer are superimposed.) As an example, take the settings shown in Figure 2. The photograph shows the translational scale set at the center, zero, and the rotational scale set at minus 2. The designation of this setting would be 0, −2, and the data sheet, Figure 3,

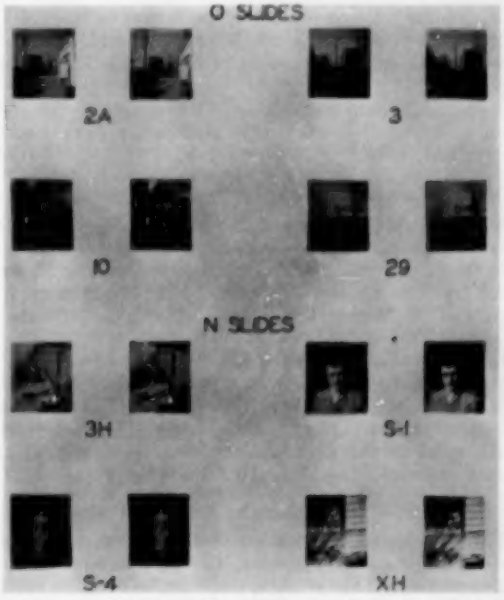


Fig. 4. Photographic subjects used in the tests.

shows a check mark denoting an acceptance by the second observer for slide 2A. The ± M figures at top and bottom of this column represent the 0.075 inch rotational settings mentioned before. A cross, as at −M, represents a rejection.

It should be emphasized that the twenty-one different rotational settings used were presented to each person in a random sequence. The same is true of the seventeen (or nineteen) translational settings. The randomization was an important part of the experiment, and yet it can easily be forgotten when looking at the regular acceptance pattern of a data sheet. It prevented undue emphasis on any specific situation, such as a borderline setting immediately following a completely unacceptable setting of the same sign or direction (which might dispose the observer to greater acceptance of the borderline setting).

Each row of the data sheet represents variation in the vertical translational misalignment of the stereo pair introduced by the adjustable mount at a fixed rotational alignment. Thus, the −6,0 box represents a position of the right-eye transparency 6 units (nominally 0.030 inch) below the left-eye transparency. Since the viewer used was found to have a −0.005 inch misalignment of its own, the true translational misalignment (assuming a perfect slide) would be −0.025 inch. This setting was rejected by this observer. The setting representing +0.025 inch, however, +4,0 was accepted. This situation indicated the presence of a vertical phoria in the eyes of the observer, with the right eye looking up.

The completed data sheets of an observer show almost at a glance how consistent that observer was at the time of rating. Reference to the translational acceptance row of Figure 3 shows that the observer rejected settings −8 through −6, was doubtful at −5 and −4, accepted −3 through +4, was doubtful at +5 and +6, and rejected at +7 and +8. This is the normal pattern of a consistent observer. Reference to the rotational acceptance column of the data sheets shows a less well-defined acceptance pattern. This is normal, also, and there will be more discussion of both areas later in the paper.

From additional records kept on the observers, the random sequence of settings used with each can be determined.

4. Slides for the Adjustable Stereo Mount

Kodachrome transparencies taken from cardboard-mounted 35mm stereo slides were inserted in the adjustable stereo mount. Two sets of four slides each were rated by the various observers. They are shown in Figure 4. Each observer rated either the O set or the N set.

Each set of slides has a wide variety of subjects as regards brightness, presence or absence of straight lines, type of subject, etc. Some of the O slides were not completely sharp. The N slides were more representative of the work of the advanced amateur, while the O slides came closer to being the casual snapshot type.

5. Rating Procedure with the Adjustable Stereo Mount

The original plans called for the presentation of various settings of each slide to the observer with no comment other than the request that he rate the setting as "accept," "reject," or "question." Practical experience, however, soon showed that it was desirable to introduce the rating problem to the observer in more detail. It was found that this could be done in such a way as to anticipate most of the questions which arose in the minds of both inexperienced and experienced people by the following procedure:

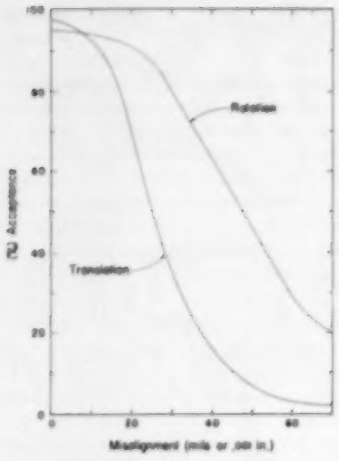


Fig. 5. Data obtained from fifty-one observers.

a. At the time of the original request to an observer to rate a slide set, the assignment was explained briefly.

b. At the start of the rating test the first slide was given to the observer with the adjustable mount set at 0,0 in the hand viewer with the instruction, "On this first setting of the first slide, please adjust this interocular lever so that the setting is right for your own eyes and focus with this knob to suit yourself, so that further adjustment is unnecessary or at least will be at a minimum during the rest of the test." The exact wording varied somewhat with the experience of the observer and among the three testers.

c. After the adjustable mount had been set to the first position required by that observer's sequence and before the viewer was returned to him, these directions were given: "We would like to have you imagine that you have just received a box of your own slides from the processing laboratory and that you are looking at them for the first time. Please look at each setting of each slide rapidly and accept or reject it on the basis of your first impression.

"*Do* base your acceptance on viewing comfort. Reject any setting which takes some time to fuse or which causes eyestrain. In other words, if you see two separate pictures at first or if you feel pain or pull in your eyes, reject the slide. If in doubt, rate the slide as "questionable."

"*Do Not* base your judgment on composition, color balance, or non-stereo areas along the outer margins of the picture."

Again the exact wording varied somewhat with tester and with observer experience. However, considerable effort was taken to present a standard set of directions of the above form to all who rated the slides, without undue formality.

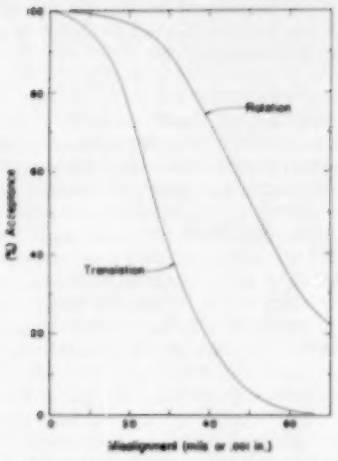


Fig. 6. Data from twenty-seven most consistent observers.

Rating time varied from less than one half hour to two hours. Since it was impossible to predict how much time a given observer would require, four appointments a day were made. Three different people conducted the rating tests.

The observer sat across the table from the tester. A black cardboard mask attached to the viewer prevented the observer from seeing the position of any part of the mechanism used to change the position of either transparency. A clip-board, with data sheets and setting sequence card, was held by the tester in such a position that none of the record was visible to the observer.

The pair of transparencies comprising the first slide called for by the slide sequence drawn by the observer were removed from the slide box by the tester, who wore white cotton gloves. They were inserted in the carriages of the adjustable stereo mount, the front masking plate was put back on the mount, any lint was removed with a soft brush, and the mount was put in the viewer, all in full sight of the observer. The tester then set both levers of the mount to zero and examined the slide to make sure the mounting was correct.

The viewer was then placed upon the slide box (which served as a convenient stand) facing the observer and was slid across the table to him with the instructions quoted under "b," above. After the observer had picked up and adjusted the viewer to his own satisfaction, the viewer was slid back across the table, the first setting was made according to the random sequence drawn by the observer, and the instructions quoted under "c" were given before the viewer was again returned across the table to the observer. After each acceptance or rejection, the tester recorded a check or a cross, respectively, in the proper box on the data sheet, received back the viewer, changed the setting, and returned it on the stand. Time was usually recorded at the beginning and end of each rotational or translational sequence of each slide. Remarks made then by the observer and other pertinent notes were recorded at the bottom of the data sheet.

Several precautions were observed in making scale settings. All settings were approached from the right (to reduce the effects of any play in the mechanisms), and both scales were re-set each time after referring to the sequence card (although only one scale was used at a time, as explained previously) so that no bias could be given to the observer.

Questions asked by observers during the test which pertained to the action of the alignment mechanism were deferred to the end of the test. Other questions, discussion of phases of stereo photography, and remarks on the test were freely dealt with during the test and notes made on the data sheets where the material seemed pertinent.

It was requested that there be no smoking during the test to avoid any possibility of spurious eyestrain or smarting.

Analysis of Data

This experiment was designed to answer a variety of related questions about observers, slides, and kind of misalignment, as well as the main question of variation in average observer acceptance level with translational misalignment. It is concerned with *the effects of changes of only a few thousandths of an inch on what people like:* i.e., *subjective judgment* is being invited to *guide precision tolerances*. Obviously, a very accurate curve is required if manufacturing decisions are to be based on it. And just as obviously, to produce such a curve it must be known whether the test has simulated the most important misalignment situations; whether the observers have made reliable judgments; whether their experience in stereo viewing or the test procedures have influenced their acceptance; and whether their acceptance curve is normal in the statistical sense. A question which cannot be answered with complete satisfaction now is how well the people surveyed represent the entire population.

In only one of the tests with the adjustable stereo mount were translational and rotational misalignment deliberately combined to all the various degrees possible with this equipment. Except where stated, percent acceptance was calculated on the basis of full acceptances only (questions treated as rejections). In all parts of this section except that on normality of distribution of results equivalent plus and minus ratings were averaged. Thus, small misalignments in the slides tended to cancel out.

Misalignments will be listed in mils (0.001 inch).

1. Translational vs. Rotational Misalignments

Figure 5 shows how all fifty-one observers surveyed rated their slides in both translation and rotation, and Figure 6 shows how the twenty-seven most consistent observers (see part 2 of this section) rated their slides in these two respects. A few of the values from these figures are summarized below:

Observer Group	Acceptance Level %	Number of Mils of Misalignment Accepted Translation	Rotation
All fifty-one	90	12	21
	50	25	47½
Twenty-seven most consistent	90	14	29½
	50	27½	52

It is obvious that a given level of acceptance can be secured in translation at about one-half the misalignment required for it in rotation.

The geometry of rotational misalignment was shown to be such that a maximum amount of misalignment exists if the two transparencies rotate in opposite directions. In fact, if each rotates an equal amount, twice the misalignment introduced by our adjustable stereo mount would result in the extreme corners. The extreme corners are not visible, so one might expect slightly more than twice the translational misalignment to be tolerable in rotation on the basis of geometry.

Another way to examine this idea is to compare the translational acceptance level at a given misalignment with the rotational acceptance level at twice that misalignment. Such a comparison is shown below for the twenty-seven most consistent observers (whose curves originate at 100% acceptance):

Translation		Rotation	
Misalignment Mils	Acceptance %	Misalignment Mils	Acceptance %
5	98½	10	99
10	95	20	97
15	88½	30	89½
20	76	40	72½
25	58	50	53½
30	41½	60	34

Here it can be seen that the rotational acceptance is slightly higher than the translational acceptance through 15 mils translation or 30 mils rotation. Although the rotational acceptance in the lower ranges drops more rapidly than the simple geometric picture would indicate, the agreement in the upper acceptance ranges is good enough so that there seems to be no need to reconsider rotational misalignment in all the various aspects for which translational misalignment will be examined in the paragraphs which follow. The variation in amount of vertical misalignment with distance from center of a slide in the case of rotational misalignment probably leads to some confusion in rating.

A supplementary test using four of the most consistent observers encountered during the first third of the regular rating test was set up to evaluate the effects of combined rotation and translation. The single slide chosen, number 3H of Figure 4, has a prominent object in the lower left corner (the E of the weather vane).

With rotation superimposed upon translation with this slide, clockwise rotation adds to downward translational misalignment of the E (−, − quadrant of the rating sheet according to the convention). Counterclockwise rotation adds to upward translational misalignment of the E (+, + quadrant). In all cases, of course, the transparency center misalignments are fixed by translation alone.

The results showed percent acceptance to hold steady in the quadrants where rotation does not add to misalignment of the E as compared to pure translational misalignment. They also showed percent acceptance to drop ten to fifteen units in the −, − and +, + quadrants where rotation does augment the translational misalignment at the E.

That test is considered to be a very sensitive confirmation of the fundamental equivalence of translational and rotational misalignment.

2. Observer Consistency

A little has already been said about observer consistency. One contribution the adjustable stereo mount made to misalignment tolerance testing was the ease with which various degrees of consistency could be evaluated. In this paper, results from observers at three levels of consistency have been analyzed. One group is composed of all fifty-one observers used, regardless of consistency. The next, slightly more select, group consists of the forty-seven observers remaining after the four least consistent observers were eliminated. The most select group consists of the twenty-seven most consistent observers. Division into the three groups was made according to the rules given below. These rules may seem rather arbitrary, but they led to a surprisingly clear-cut division of observers.

The four least consistent observers were those who showed either more than five inconsistencies or more than twenty-five questions on their translational records alone. An inconsistency consists in a rejection (X) in an area where the bulk of the data on that particular data sheet show the observer should have accepted (√), or vice versa. Half an inconsistency consists in a question (?) where the record shows a rejection or an acceptance should be, or either a rejection or an acceptance in a region which should have been questioned. The rational arrangement which results in a minimum of inconsistencies was chosen.

More criteria were used in the selection of the twenty-seven most consistent observers. Any observer who had more than two inconsistencies or more than seventeen questions on the four sheets of his translational record or who had a rejection or more than two questions in the middle five blocks of his four rotational records was eliminated.

Some of the advantages of using the group of twenty-seven most consistent observers will have become obvious already. Figure 6 shows that both their translational and rotational acceptance curves can start from one-hundred percent acceptance at no misalignment. This, in itself, is evidence that the observers get a clear-cut reaction to the main variable. They know when they are viewing comfortably with considerable certainty. Although not shown, experimental points for the twenty-seven vary less from the average acceptance lines than do those of all fifty-one observers. More accurate curves can be drawn. The analysis of their rotational acceptance shows somewhat closer agreement with what might be expected from geometrical consideration. These are mainly indirect indications.

In addition, the twenty-seven most consistent observers constitute a rather well-balanced group. Fourteen rated O slides, and thirteen rated N slides. There were nine observers each of beginners, intermediates, and experts. In terms of the translation-rotational sequences used, eight viewed all slides first in translation, five viewed all slides first in rotation, seven viewed each slide first in translation and then in rotation, and seven viewed each slide first in rotation and then in translation. The proportion of women is low (15%), but it is about the same as that among all fifty-one

observers (18%), indicating no strong selective tendency due to sex.

The progressive effect on translational acceptance of more and more consistent observers will be seen by comparing the best line averages shown for fifty-one observers vs. forty-seven vs. twenty-seven in Figure 7. One would expect that the completely random rejections by an observer who does not see in true 3-D would account for a lower acceptance at near-perfect settings and for higher acceptance at very low misalignment. This is the situation shown in Figure 7.

A larger group has a better chance of being representative of the general population. The advantage of using all fifty-one observers instead of the forty-seven normal and consistent people is, of course, more than compensated for by the inconsistent and indecisive judgments rendered by the four "least consistents." The numerical advantage of using the forty-seven over the twenty-seven is more pronounced. It was considered necessary to examine the two groups in more detail.

To decide whether there was any fundamental difference in range between the groups of forty-seven and twenty-seven observers, the data were analyzed for the effects of indecision as well as of inconsistency. Figure 7 shows the group of forty-seven to be lower in the regions of high acceptance and higher in the regions of lower acceptance. This, as was stated above, is what one would expect from random inconsistencies. Figure 8 shows how the twenty-seven most consistent people compared with the twenty normal people when indecision was eliminated by scoring questions as acceptances to remove the "not sure" area. As will be seen, the two groups were almost identical in the regions of high acceptance and were close enough throughout to warrant drawing a single curve.

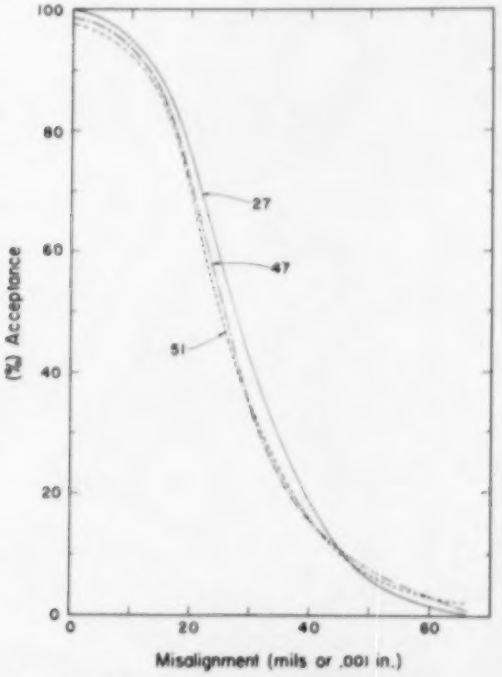


Fig. 7. Observer consistence and acceptance of misalignment: ——27 most consistent observers; ——·——·——47 consistent and normal observers; - - - - all 51 observers.

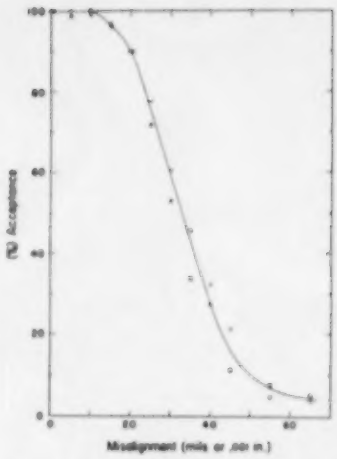


Fig. 8. Data from 27 consistent observers —○—○—○— and 20 normal observers □—□—□— with indecisions scored as acceptances.

For these reasons, most of the curves shown in the remainder of this report will be for the consistent group.

3. Stereo Viewing Experience

Approximately one-third of the observers who rated slides were from each of the three experience categories: beginners, intermediates, and experts. The dividing line was as follows:

Beginners were those who had looked at no stereo slides in the hand viewer or, at the most, several slides.

Intermediates were those who had looked at several sets of stereo slides in a hand viewer.

Experts were those whose interest in stereo photography had been great enough so that they had engaged in it as a hobby or those who had viewed many stereo slides in connection with their work.

Figure 9 shows that the twenty-seven most consistent observers show no definite trend with experience. There were nine observers in each category, and the beginners and experts gave fairly similar records. The intermediates proved to be most distinctly different. They are also a somewhat less consistent group, with less than one-hundred percent acceptance at zero misalignment.

The data for all fifty-one observers (16 each beginners and intermediates and 19 experts) also show a trend to lower acceptance by intermediates, with beginners and experts more nearly alike and with higher acceptances than intermediates at any misalignment.

It was concluded on the basis of these few tests that there was at least no marked trend in acceptance pattern with experience in viewing hand-held stereo.

4. Order of Viewing Slide (Fatigue)

Many people had expressed the view that fatigue would lower the acceptance level on successive slides. On the other hand, there was the distinct possibility that

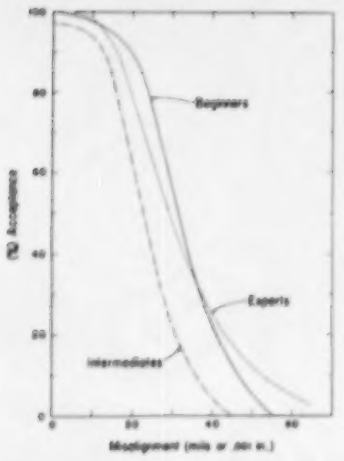


Fig. 9. Twenty-seven most consistent observers show no definite trend attributable to experience.

skill in viewing might affect the acceptance range in either way: the observer might be able to tolerate more misalignment or he might become more discriminating and reject more.

Figure 10 shows no definite trend in either direction, so a single line has been drawn.

5. Type of Slide

If the acceptance figures are plotted for the twenty-four observers who rated the O slides separate from those for the twenty-three observers who rated the N slides, there is no clear-cut distinction. Acceptance averaged lower for the O slides in the middle range (twenty to forty-five mils) but was almost identical at both the extremes of good and bad alignment.

A somewhat similar plot results when the ratings by the twenty-three observers who looked at N slides are graphed for slide S-1, taken at two and one-half feet, and S-4, taken at ten feet. Here there is a middle range where the more distant slide receives a lower average acceptance. Again, the extremes are indistinguishable. Thus, closeness does not seem to be a major factor.

A third division which comes under slide type can be made: this involves the presence or absence of prominent, straight, horizontal lines which extend to the picture edge. To test this idea, a pair of slides illustrating each case was chosen from each set of slides. Thus, all forty-seven observers looked at a slide of each type, whether it was one of the O or one of the N slides. Data from translational acceptance showed a possible trend to lower acceptance with such lines present. Rotational acceptance data showed a strong trend toward this situation. However, the largest difference indicated, about three percentage units, is very small.

There seems to be little average effect by type of slide.

6. Translational-Rotational Sequence of Viewing

Acceptance data from the forty-seven consistent and normal observers were separated into the four groups:

(a) All Slides looked at first with variations in translational alignment.

(b) All slides looked at first with variations in rotational alignment.

(c) Each slide looked at first with translational alignment variations and then with rotational alignment variations before proceeding to the next slide.

(d) Each slide looked at first with rotational alignment variations, then with translational, before proceding to the next slide.

There were eleven observers in group (a) and twelve observers in each of the other three groups. The averages of each group were graphed.

The results showed no clear-cut separation by group. It is believed, nevertheless, that the randomization of this factor and others which did not produce definite patterns is worthwhile for tests of this sort.

7. Individual Variations in Acceptance Range

Figure 11 shows how widely two observers varied in their tolerance for translational misalignment. Both of these people were very consistent. Each question has been scored as one-half an acceptance.

It can be seen that observer number 40 has a very wide tolerance, accepting all settings on all four of his slides out through 0.045 inch misalignment. Observer number 51, on the other hand, accepted less than one-hundred percent of his settings even at 0.010 inch. By 0.030 inch he found nothing comfortable.

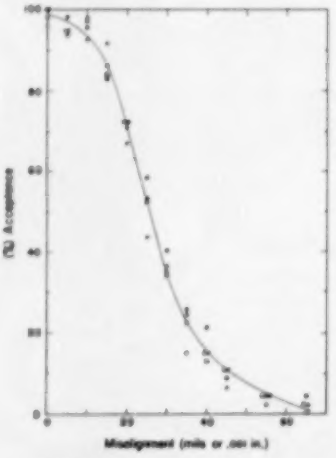


Fig. 10. Fatigue and acceptance of translational misalignment: (○) first slide viewed, (□) second slide viewed, (△) third slide viewed, (●) fourth slide viewed.

Although the two cases represent the extremes, they are well to bear in mind when interpreting data from small numbers of observers. Obviously one of these individuals could cause quite a measurable shift in averages if included in a small group.

The records of these people also show the wide variation in individuals the stereo manufacturer may be called upon to please.

8. Normality of Distribution of Data

Figure 12 shows how acceptance data from the adjustable stereo mount compare with normal distribution curves. The number of acceptances is plotted

against misalignment, after correction for viewer misalignment but before the combination of acceptances for plus and minus values of misalignment.

The curves drawn in Figure 12 are those defined by the equation:

$$y = ke^{-h^2a^2}$$

For the top curve, the values of the constants used were k=204 and h=0.0326. The experimental points with which it may be compared are those for all fifty-one observers. It will be seen that the "best" curve through the experimental points would be broader and flatter at the top and shifted a small amount to the right. This could indicate that the data were over-corrected for viewer misalignment.

The lower curve was drawn using values of the constants of k=108 and h=0.0326. The experimental points are those for the twenty-seven most consistent observers. Here, again, a slight shift of the experimental curve to the right would be indicated. The most consistent observers show the same type of symmetrical curve, rather broad and flat at the top, as do all observers. However, their acceptance at zero misalignment comes closer to the theoretical of 108 acceptances in 108 ratings.

Both sets of data are reasonably normal for the problem in hand, and the average vertical phoria of either or both groups of observers could affect the zero position of the curve as well as a viewer, slide, etc., correction. The data were, therefore, not corrected on the basis of this treatment. Since the distributions can be considered normal, the simple averaging of acceptances for plus and minus values of misalignment will lead to very accurate values of percent acceptance in the range of 5 mils through 35 mils, and the drawing of a smooth curve through all points beyond this region will further decrease possible errors.

9. Selection of the Best Curve

In the foregoing analysis of the data, an attempt has been made to present the most important points which influence picking a "best" curve.

First, it was shown that the similarity between translational and rotational vertical misalignment expected

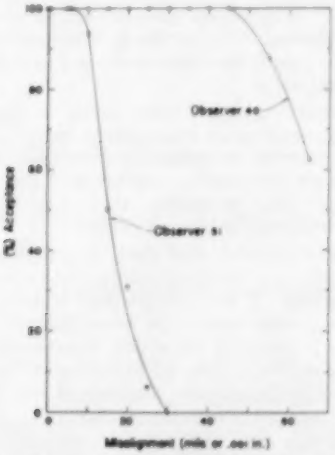


Fig. 11. Extreme of individual variations in acceptance of misalignment among 51 observers.

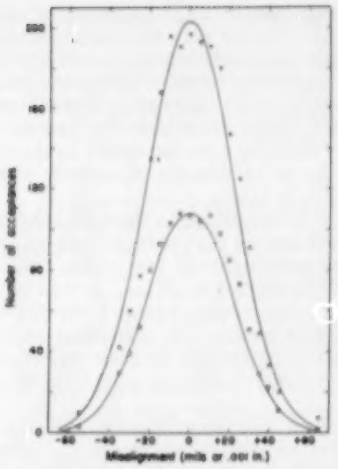


Fig. 12. Normality of distribution of misalignment data. The upper curve is for all 51 observers, the lower curve for the 27 most consistent observers.

theoretically was found experimentally. Translational misalignment was picked as the more desirable means of measurement. Next it was shown that the most consistent group of observers gave best results because they were more accurate and certain of their comfortable range of viewing, without differing in their average tolerances to misalignment from the "normal" observers.

Factors such as experience in viewing stereo, fatigue, type of slide, and translational-rotational sequence of viewing were found to have little effect upon the average results. Since care was taken to vary such factors within the test, there is considerable assurance that any small effects based on these factors have been cancelled out.

Finally, it was shown that the distribution of the data is reasonably normal in the statistical or mathematical sense.

The remaining questions seem to be these:

(a) Is the rather small group of people worked with adequate to represent the general population?

(b) Should a question mark be treated as an acceptance, as a rejection, or as half an acceptance?

It seems safest, in view of the wide variations we have found among individuals, to regard the present results as preliminary. And the compromise solution of counting a question as one-half an acceptance seems reasonable.

Figure 13 is therefore presented as the best preliminary curve of average viewing comfort as influenced by vertical misalignment. It differs from the translational results shown in Figure 6 only in that it gives some weight to questions.

To transform results shown by Figure 13 from thousandths of an inch to minutes of misalignment, multiply by two. This is the approximate relationship for the viewer used, which has 44mm lenses.

Significance of the Acceptance Curve

Figure 13 is for hand-viewed stereo, as pointed out before.

Consider the case of a manufacturer of stereo equipment who has decided that he wishes to please ninety percent of all potential customers. If the above data prove to be valid after further testing, his total tolerance is about 17 mils (0.017 inch) with 44mm viewing lenses or 34 minutes. This means that his camera, his viewer, his filters (if used), and his mounting service must divide these 17 mils or 34 minutes in such a way that this total tolerance is held.

Conversely, a manufacturer may already have extensive measurements on his products, and he may wish to know what percentage of the public his goods and services can be expected to please. It will be easy to add maximum misalignments, of course, but this will furnish little basic information. A statistical analysis of the misalignment distributions in their relationship to the type of acceptance curve presented in this report is needed.

If more than one manufacturer is involved in the sequence of operations which produce a slide, the problem becomes one for standards consideration. Not only must some division of the total observer tolerance be made among the various items of equipment and service, but even the level(s) of acceptance desired must be agreed upon. Perhaps, A, B, and C levels would be necessary, leaving the consumer to decide which range was satisfactory for his use.

The individual has a somewhat different problem, that of checking and controlling his own work. His checking may well start with his own eyes: among other things his optometrist or ophthalmologist can tell him the magnitude and direction of any vertical phoria present. Although space does not permit covering the various simple means available for checking camera, viewer, and mounting, it should be mentioned that a person with no vertical phoria can shim his viewer to almost zero misalignment by visual observation of a well-aligned slide. A stereo projector can also be used to estimate misalignment if a well-aligned slide is available to set the projector. A carefully scribed blank slide can serve this purpose. The lines should extend across both transparencies and must be parallel to the same edge of the slide used to seat in the projector.

Acknowledgments

Many people within the Eastman Kodak Company contributed to the preparation of this paper. The help of most cannot be acknowledged here, but the author would like to mention Mr. E. Jewett, for design work on the adjustable stereo mount, Mr. R. Freund for statistical design of the experiment, Dr. S. Newhall for phychological consultation, and Drs. E. Bauer and J. Hale for general assistance and supervision.

Conclusions

1. The acceptance range of only a limited number of observers has been studied. The average results secured should be treated as indicated, rather than as final, values.

2. The average observer has a very clear-cut reaction to stereo slides as their homologous images are moved out of vertical alignment. Over a narrow range he views with perfect comfort. With greater misalignment, his eyes have to work a little harder, and he is less certain of comfortable viewing. Then misalignment makes his eyes work definitely harder, until he can no longer fuse the images into a single picture. If a curve of percentage of comfortable viewing is plotted against thousandths of an inch of misalignment for a given viewer, a reversed S-curve results.

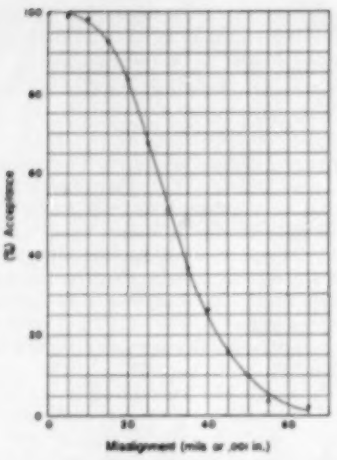


Fig. 13. Reference curve of average viewing comfort as influenced by vertical misalignment.

3. Discomfort from rotation of one transparency about its center is quite similar to that experienced as a result of moving one transparency up or down,—so similar that it may be possible to explain the main quantitative differences on the basis of simple geometry.

4. The average observer's comfort of viewing was surprisingly free of influence from: previous experience in viewing stereo, type of slide, closeness of subject, and fatigue. Closest subject was two and one-half feet. Ratings were on different settings of four slides for each observer and took over an hour in some cases.

5. Wide variations were found in the amount of misalignment in a stereo slide which is acceptable to different observers. By securing complete test ratings from fifty-one different observers, a fair average was probably obtained.

6. It seems inevitable that some division of the average observer's small tolerance to misalignment will eventually have to be made by standards association action. People who make cameras will have their few thousandths; slide mounters, their few thousandths; and viewer makers, their small range.

7. The test method used made it possible to distinguish between consistent and inconsistent observers with considerable ease. It was also possible to detect observers who favor a certain amount of misalignment and to tell whether they preferred the right transparency high or low. (Such an observer is said to have a vertical phoria.) These factors facilitated the analysis of the data.

8. The percentage of female observers rating the stereo slides was low, 18%; but it remained almost the same (15%) in the select group of consistent observers, indicating that very marked differences are not present.

9. The distribution of the acceptance data from the adjustable stereo mount was normal in the statistical sense.

References

1. H. C. McKay, Three-Dimensional Photography, New York, American Photographic Publishing Company, 1953.

2. K. N. Ogle, Researches in Binocular Vision, Philadelphia, W. B. Saunders Company, 1950.

3. R. A. Sherman, Benefits to Vision Through Stereoscopic Films, Journal of the SMPTE, Vol. 61, pp. 295-308, September, 1953.

4. D. L. MacAdam, Stereoscopic Perceptions of Size, Shape, Distance, and Direction, Journal of the SMPTE, Vol. 62, pp. 271-293, April, 1954.

CHARACTERISTICS OF THE NEW ANSCOCHROME TYPE PRINTON FILM

John R. Kane*

Anscochrome type Printon film is a reversal color printing material designed for single exposure printing. It is particularly suited to production printing as in color photofinishing. New Anscochrome type Printon film is the result of over ten years experience in manufacturing the previous type of Printon material. A continuous research and development program has been carried out during that time working closely with the independent color finishing industry.

New Anscochrome type Printon film represents the cumulative result of many improvements which, while not individually spectacular, together add up to a product engineered specifically for the independent color finishing operation. While many improvements have been made, the basic concepts of Printon film have not been changed. This is a consequence of the designing and planning which went into the original Printon film that was released for general use on November 15, 1945.

To properly evaluate the characteristics of Printon film, one must keep in mind that it is a color material intended for use in printing snapshot type transparencies. These original color transparencies frequently suffer from under- or over-exposure and excessive lighting contrast. It is also important to remember that Printon film is used under production line conditions rather than studio or laboratory conditions so economical operations and ease of handling the material are very important considerations.

The major features of the new Anscochrome type Printon film, established through more than ten years of close cooperation with the independent color finishing business, are:

* Technical Service Department, Ansco Division of General Aniline & Film Corporation, Binghamton, New York.

To be presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York, 25 and 26 May, 1956. Received 30 March, 1956.

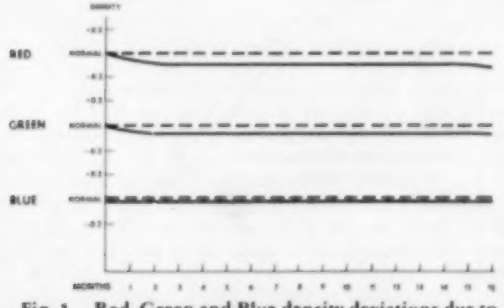


Fig. 1. Red, Green and Blue density deviations due to aging of unexposed, undeveloped Printon material stored at 70 F over a 16 month period. Maximum deviation was 0.1 Red density (cyan dye). The material stabilized at about 4 months which is about the time it reaches the finisher.

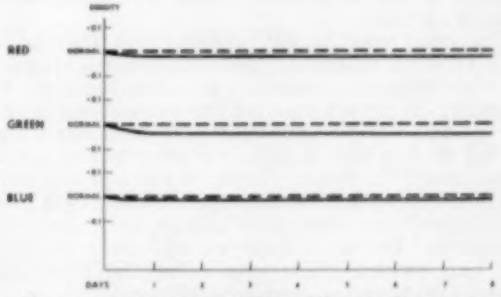


Fig. 2. Latent image stability of Printon film over an 8 day period. Maximum deviation is approximately 1/10 stop.

1. *Storage Stability*. Printon film may be stored under normal laboratory conditions for several weeks without deteriorating. This inherent stability allows the color finisher to stock adequate amounts of sensitized material to insure continuity of operations, without buying, building or operating special refrigerated storage facilities. In the use of Printon film, it is not necessary to unload roll head printers or collect unused sheets of Printon for return to cold storage at the end of each day or the start of each weekend. Figure 1 illustrates the storage stability of the new Anscochrome type Printon film over a period of 16 months. This chart represents the red, green, and blue density deviations from a normal density of 1.0. The maximum deviation is equivalent to only $^1/_3$ stop exposure for the red (Cyan) layer.

It is important to note that the change which occurs during storage stabilizes at about 4 months and very little change occurs thereafter. This fact should be of interest to the color finisher since most materials are approximately four months old when they go into the finishing plant. If the color finisher maintains a raw material inventory equal to one month's use, the change which occurs during this period is so slight that it is of no consequence to the finished prints.

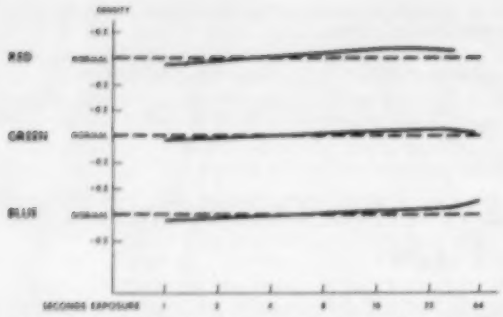


Fig. 3. Reciprocity response of Anscochrome type Printon film at various exposure times. The response is essentially the same for all layers throughout most of the range illustrated. No correction is needed for color balance throughout most of the range and only a minor speed adjustment is required. Normal exposure time is 4 seconds.

2. *Printing Speed.* The new Printon film features a printing speed level which is optimum for efficiency with either conventional or custom equipment. Seconds saved in printing time become labor dollars in the finisher's pocket.

The speed level of Anscochrome type Printon film makes possible the use of relatively low wattage standard enlarger lamps in commercially available enlargers. For example, the use of a standard 150-watt enlarger lamp in a condenser enlarger provides enough illumination for 1 second or even shorter exposures when making 2× enlargements. On the other hand, 16 x 20 and even larger prints can be made using the same equipment, still maintaining exposure times short enough for a production operation. The use of a low wattage source minimizes the heat problem. The long useful life of the light source (300 hours) is an added advantage.

The ideal speed level of Anscochrome type Printon film, of course, minimizes the problems involved in designing and constructing custom equipment.

3. *Latent Image Stability.* Latent image stability is excellent under normal storage conditions. Prints need not be processed immediately after exposure for fear of changes of speed or color balance. This characteristic allows prints exposed on Friday afternoon to be held over for processing until Monday morning. Figure 2 illustrates the latent image stability of the new Printon film at 70 F for a period up to 8 days. The maximum change noted was a density loss of the magenta dye layer approximately equal to $^1/_{10}$ of a lens stop in equivalent exposure. It is doubtful that this change could be detected except by use of a densitometer.

4. *Reciprocity Law Failure.* Reciprocity law failure is not a problem with the new Anscochrome type Printon film. There is no need to change filtration or to apply a correction factor to exposure timing over the range of exposures normally used in color printing. Figure 3 illustrates the reciprocity response of the new Printon film to exposure times ranging from 1 second to 64 seconds. The maximum change noted is less than $^1/_3$ lens stop. It is important to note that the response is essentially the same on all layers. Therefore, there is no problem of color imbalance introduced by reciprocity law failure.

5. *Acutance.* The new Printon prints are as sharp as optical equipment makes them. There is no bleeding of colors from one area to another with the result that Anscochrome type Printon film gives the visual impression of maximum sharpness and brilliance.

6. *Physical Features.* The physical dimensions of Printon film such as base thickness, emulsion thickness, etc., are such that Printon material may be easily used in roll head printers, roll easels or sheet easels. Printon film thickness is only slightly greater than that of single weight black-and-white papers permitting economical roll lengths in magazine type printers.

7. *Processing Adaptability.* Processing of Printon film must follow certain prescribed routines but it may be readily and easily accomplished in either rack and tank or continuous processing equipment. For rack and tank operation, the rigidity of the pure white safety base film support allows the use of conventional sheet film developing hangers without danger of the prints falling out when they become wet.

The stiffness of the acetate base also allows easy handling of photomural size prints by a single operator. The physical strength of Printon film makes it particularly suited to continuous processing operations, as does the minimum amount of water elongation and other swelling symptoms. The low water absorption characteristics allow rapid drying without curl or buckle.

8. *Universal Processing Line.* Most color finishers appreciate the fact that Printon film, Anscochrome film and Ansco Color Duplicating film may all be processed in a single line. This possibility minimizes the initial investment in color finishing equipment and reduces the requirement for chemical control and labor cost.

The universal processing line is provided by simply adding two developer tanks to a line which has been originally set up for only one type of film.

9. *Replenishment of Solutions.* Printon processing solutions may be replenished for maximum economy and stability of processing. They are no more critical in keeping quality than ordinary black-and-white processing solutions. While chemical savings are affected by replenishment, the maximum value is in the fact that shutdowns for dumping and remixing are greatly reduced.

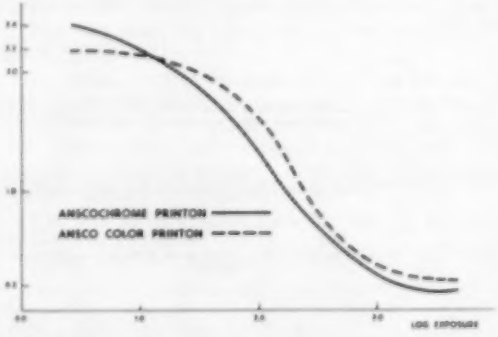


Fig. 4. Visual density curves for Anscochrome type Printon film vs. the former Ansco Color Printon film. Anscochrome type Printon film features lower stain level, higher D_{max} and a much greater exposure scale for the reproduction of snapshot type color transparencies.

10. *Maximum Brilliance.* Brilliance is obtained without ferrotyping or other costly time consuming steps.

In addition to the above factors, the new Anscochrome type Printon film features: (a) Exceptionally clean whites for better print highlights and better white borders. (b) Improved gradation for better highlight and shadow detail and extended printing latitude. (c) Good curve conformity results in excellent printing filtration characteristics. (d) Redder reds for more accurate color rendition. Figure 4 illustrates sensitometrically some of the improvements just mentioned.

The new Printon film features much lower stain level which, of course, results in clear whites and generally better quality and brilliance. The maximum density of the combined layers is considerably higher and the exposure scales have been extended to more easily handle the density ranges found in snapshot type transparencies. Both photographically and physically, the new Anscochrome type Printon film provides the commercial photofinishing operation with a color print material on which high quality duplicate prints of color transparencies can be made with sureness and economy.

PROCESSING E. I. 32 ANSCOCHROME FILM FOR HIGHER AND LOWER EXPOSURE INDEXES

Philip M. Mikoda*

SUMMARY

The introduction of high speed color film has stimulated a demand for still higher speeds. Anscochrome film permits the color finisher to obtain exposure indexes up to 125 by merely changing the time of first development and color development without any other departures from the normal Anscochrome processing procedure.

THE WRITER'S INTRODUCTION to photofinishing took place eighteen years ago when he visited the back room of the leading camera shop in his home town. This shop did what was considered the best black-and-white finishing in the area. A high school Science professor managed both the finishing plant and a camera counter on a part-time basis. Other finishing plant employees were Science class honor students, also on a part-time basis. Processing controls consisted of an employee's right index finger which served as a thermometer and a pack of regular size cigarettes which served as timers. The cigarette was lighted; several puffs were taken to get it going; it was then placed on the edge of a table; when the paint began to smell, it was time to transfer something in the darkroom or take prints off the dryer.

The successful black-and-white finisher of today has come a long way from such primitive beginnings. The modern photofinisher concerns himself with electronic controls, pH meters, sensitometry, statistical control charts, chemical analysis and in a few instances is the proud but somewhat uneasy employer of a control chemist. Every modern piece of equipment in a photofinishing plant today is automatic or at least semi-automatic. All of this is the result of the tremendous increase in volume of black-and-white business and the problems inherent in continuous processing systems.

This same type of revolution is taking place in the color finishing business. Less than fifteen years ago, only skilled technicians in the photographic industry were able to produce acceptable color transparencies and prints. In 1944, however, the introduction of Ansco Color Sheet Film made it possible for the user to produce good color transparencies within two hours after exposure. In 1946 the introduction of Ansco Color roll film along with Ansco Color Printon film made Color Photofinishing a reality.

Table I

NORMAL ANSCOCHROME PROCESSING PROCEDURE FOR EXPOSURE INDEX 32

Step	Solutions	Minutes at 68F
1.	First Developer	16
2.	Short Stop*	2
3.	Hardener	4
4.	Wash	5
5.	Second Exposure	1 (Each Side)
6.	Color Developer	14
7.	Short Stop**	2
8.	Hardener	4
9.	Wash	5
10.	Bleach	5
11.	Wash	5
12.	Fixer	8
13.	Wash	10
14.	Final Rinse	2

* For use dilute 1 part formula with 2 parts water
** For use dilute 2 parts formula with 1 part water

To increase the independent finishers' volume, a product was still needed that would fulfill the unsatisfied yearnings of the box camera owner for color pictures. Last spring, a color rollfilm with a speed three times that of any previously available reversal color roll film was placed on the market under the name Anscochrome film. This was a product with gradation characteristics ideally suited for Printon duplicates. Since the intro-

* Quality Control Department, Ansco Division of General Aniline and Film Corporation, Binghamton, New York. To be presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York, 25 and 26 May, 1956. Received 2 April, 1956.

Table II

PROCESSING FORMULA CONTROL DATA FOR ANSCOCHROME FILM

	Normal pH fresh	Useful pH range	Exhaustion rate sq. in. per liter	Keeping quality in use
First Developer (502 A-2)	10.19	10.09–10.29	640 With Replenishment	One month
First Developer Replenisher (#502R-5)	10.15	10.05–10.25		Two weeks
Color Developer (#607)	10.80	10.73–10.87	640 With Replenishment	One month
Color Developer Replenisher (#607R-1)	10.69	10.59–10.79		Two weeks
Short Stop (#858)	4.80	4.50–5.80	640	Two weeks
Diluted 1-2 Short Stop (#858)	4.80	4.50–5.80	640	Two weeks
Diluted 2-1 Short Stop (#859)	5.20	5.00–5.80	320	Two weeks
Hardener (#901)	3.50	3.20–3.80	640	One week
Bleach (#716-1)	4.70	4.50–4.90	640 With extended times 80–320 per liter 5 min. 320–640 per liter 8 min.	One week
Fixer (#800B)	8.00	7.90–8.10	640	Two weeks
Final Rinse	7.50	7.00–8.00	640	Two weeks

duction of Anscochrome film and other higher speed color films, interest in color finishing has rapidly increased. To keep pace with this interest Ansco is doing everything it can to accelerate customer interest in order to broaden the color photofinisher's volume.

Optimum Results at E. I. 32

Although Anscochrome film is designed and manufactured to produce optimum results at E. I. 32, the release of this high speed color film has stimulated a demand for still higher speeds. At E. I. 32, Anscochrome film produces optimum quality in terms of gradation characteristics, color balance and grain structure. At this speed level Anscochrome film characteristic curves show excellent conformity of the three color components throughout the exposure scale. This characteristic permits good color balance to be maintained from the highlights to the shadows; it also permits processing to obtain higher than normal effective speed.

Any deviation from the E. I. 32 procedure results in slight quality losses; at E. I. 64 these losses are scarcely perceptible; at E. I. 125 the losses become visible, gradation steepens, maximum density drops a noticeable degree. The results, however, are still good. Both still and motion picture photographers were quick to experiment and to find that speeds up to E. I. 125 were obtainable by changing developing times only. Many photographers are now routinely exposing Anscochrome at exposure indexes up to 125. The progressive photofinisher should be prepared to handle these growing requirements for high speed color finishing.

The processing procedure and formulas recommended for optimum results with Anscochrome film are shown in Table I and Table II. All of the chemicals required are available in the new 3½ gallon size Anscochrome Professional Developing Outfits. For the volume color finisher the First Developer is supplied in factory-packed units to make 10 gallons of solution. A Replenisher formula for the First Developer is likewise furnished in quality controlled packaged chemicals to make ten gallons of solution. The Short Stop and the Hardener are normally mixed by the color finishers on the premises. They contain familiar photofinishing chemicals which are readily available.

The Second Developer, or Color Developer, is carefully compounded and made available in factory sealed cans for making ten gallons of solution. A Replenisher formula for the Color Developer, likewise, is supplied by Ansco, packaged in 10 gallon units.

The Bleach formula comes ready prepared for dissolving in water to produce ten gallons of working solution. The Fixer and the Final Rinse both are prepared by the finisher from familiar ingredients.

The normal formulas for normal processing of Anscochrome Film are the same formulas used to produce higher speed results without the use of any accelerators. The color finisher needs only to follow the developing time changes in Table III.

Anscochrome films are now being furnished in sheet and roll form for both amateur and professional use. They are supplied in color balance suitable for daylight photography and with different color balance suitable for artificial light of various "color temperatures." Processing any one of these films under carefully controlled conditions produces results at exposure indexes of up to 250 which have been considered satisfactory for information gathering purposes.

The color finisher of today should be on the alert for new uses for his services. He should concern himself not only with the advanced amateur as in the past but

Table III

ANSCOCHROME SPEED VARIATION TIME TABLE

Exposure Index	Developing Times First	Color	Suggested filter to restore color balance
8	9	9	
16	12	12	
32	16	14	
64	21	16	
100	23	16	.025 B
125	30	20	.10 B

with the possibility of servicing industrial, commercial, and professional users of color photography as well. With an Anscochrome film processing installation, the enterprising color finisher can now service the box camera user, the advanced amateur and professional photographer without changing a solution or processing time. With slight change in developer times he can offer a premium-priced service to the high speed color user.

In addition color finishers should not overlook the rapidly increasing use of 16mm high speed Anscochrome film in industry. The demands for this material are expanding rapidly. Some applications of this product processed to E. I. 125 are: Spot News for Color TV, Flame Growth Studies, Highway Construction Research, High Speed Flow Analysis, High Velocity Mechanical Motions, Vibration Analysis, Ballistics, Night Sport Events. A properly equipped color finisher can handle these 16mm processing requirements in his neighborhood with relatively simple equipment.

An Anscochrome film processing installation is the most versatile color finishing operation available today. Strict adherence to processing instructions will produce highest possible quality. Whenever these instructions appear difficult or expensive to follow, it may be well to keep in mind the words of a man who knows, the proprietor of a well-known color finisher Service, who said, "Black-and-white finishing pays for your bread and butter; color finishing pays for your Cadillac."

SENSITOMETRIC CHARACTERISTICS OBTAINED WITH KODAK SD-19A DEVELOPER

P. Hariharan*

ABSTRACT

Sensitometric data for two high speed, panchromatic, negative emulsions developed in Kodak SD-19A developer are presented. The variation of the sensitometric properties with the development time and the delay interval after the working solution is mixed, as well as the keeping properties of the stock solutions, are discussed.

The experiments described in this paper were undertaken in the Division of Applied Physics, National Research Council, Ottawa, Canada, with the object of studying the characteristics of Kodak SD-19A High Emulsion Speed Developer.[1] That formula (see Table I) utilizes the ability of certain hydrazine derivatives, when added to a normal photographic developer, to give increased emulsion speeds.[2] Part of this work, consisting of an evalution of the film speeds obtained on the resolving power criterion, has been published elsewhere.[3] The present paper deals, in more detail, with the general sensitometric properties of two high speed negative emulsions developed in SD-19A.

Tests were carried out with two panchromatic negative films: Kodak Aero Super XX and Kodak Super XX sheet film. Samples of these were exposed in a sensitometer through a calibrated Kodak No. 2 step tablet to a standard source consisting of a projection lamp run at a color temperature of 2860 K, and a Davis-Gibson liquid filter.[4] The exposure time was 0.029 second.

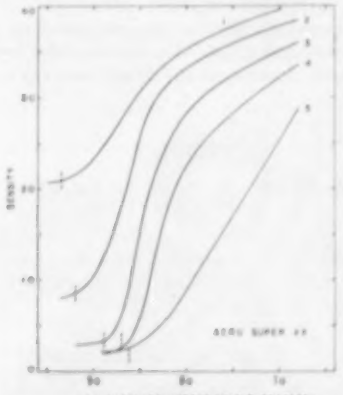


Fig. 1. Characteristic curves for Kodak Aero Super XX film, developed in SD-19A for 18 minutes with delay intervals of (1) 30 sec., (2) 2 min., (3) 5 min. 30 sec., and (4) 15 min. 30 sec. The control curves (5) for development in D-19, for the same time, are included for comparison.

*National Physical Laboratory of India, New Delhi, India. Received 26 March, 1956.

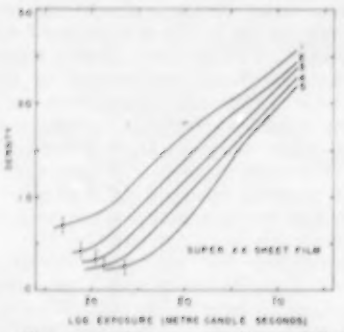


Fig. 2. Characteristic curves for Super XX sheet film developed as described in Fig. 1.

The exposed film strips were developed in a spiral tank. Since it was found, quite early in the investigation, that the activity of the developer decreased rapidly after the working solution was prepared,[3] the two stock solutions were mixed together in the tank. The film reel was lowered into the working solution, to initiate development, after a measured delay interval. Development times ranged from 5 minutes to 18 minutes and the delay interval was varied from 30 seconds to 15 minutes and 30 seconds. The degree of agitation was controlled by shaking the whole tank to and fro continuously for the first minute and for eight seconds in every quarter minute after that. Control strips were developed in D-19 according to the same procedure.

Experimental Results

Representative characteristic curves for Kodak Aero Super XX film and Kodak Super XX sheet film for a development time of 18 minutes in SD-19A and various delay intervals are shown in Figures 1 and 2. The sensitometric curves for development in the unmodified formula D-19 for the same time are included for comparison. The minimum exposure permissible on the fractional gradient criterion[4] is also indicated on each curve.

As can be seen from the curves, the sensitometric characteristics depend on the delay interval as well as on the development time. The variation of the sensitometric characteristics with the development time and the delay interval are discussed under the following headings:

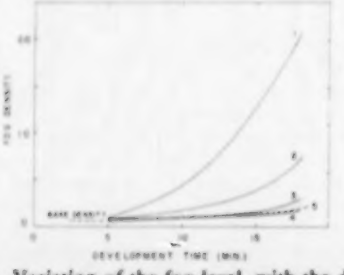


Fig. 3. Variation of the fog level, with the development time, for Kodak Aero Super XX film developed in SD-19A with delay intervals of (1) 30 sec., (2) 2 min., (3) 5 min. 30 sec., and (4) 15 min. 30 sec. The control curve (5) for development in D-19 is included for comparison.

1. Fog.

The time-fog curves obtained for development in SD-19A are of the usual form. However, the fog density for any development time depends on the delay interval. Very high fog levels are attained when the delay interval is reduced to a minimum. On the other hand, with delay intervals exceeding 15 minutes, the fog density is practically the same as that obtained with development in D-19. The variation of the fog level with the development time, for different delay intervals, for Kodak Aero Super XX film, is shown in Figure 3. The curves obtained with Kodak Super XX sheet film are of the same form, except that the fog levels are not quite so high.

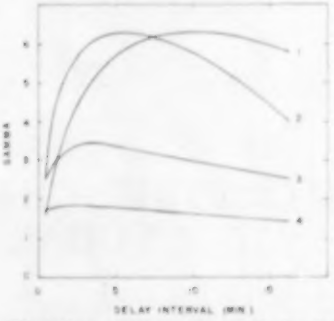


Fig. 4. Variation of the gamma with the delay interval for Kodak Aero Super XX. Development times of (1) 18 min., (2) 13 min., (3) 8 min., and (4) 5 min., in SD-19A.

2. Contrast.

With both the films studied, development in SD-19A results in comparatively low values of gamma when the delay interval is short. This is partly because of the high fog level. As the delay interval is increased, the contrast increases. In the case of Kodak Super XX Sheet film, this increase is quite small and the gamma always remains below that obtained with development in D-19, but for Kodak Aero Super XX film the increase is quite striking, especially with the longer development times. Figure 4 illustrates the variation of the gamma of Kodak Aero Super XX film with the delay interval for various development times in SD-19A. Extremely high values of gamma can be obtained under certain conditions.

3. Grain.

Development in SD-19A results in very grainy negatives, with a grain pattern of a peculiarly "woolly" nature.[3] The grain is most prominent in the background fog and in the low density areas of the image. This is probably because the larger reservoir of undeveloped silver in these areas results in a proportionately greater density being built up by the fogging action of the developer. When the delay interval is kept to a minimum, a granular type of fog appears, consisting of round dots of high density ("pepper"), so that satisfactory enlarge-

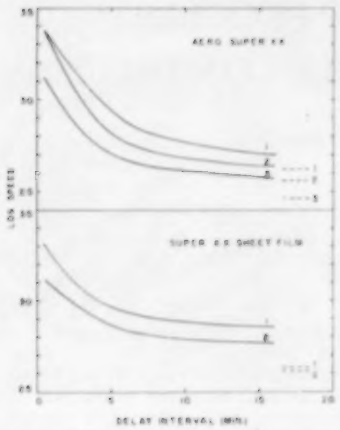


Fig. 5. Variation of the fractional gradient speed with the delay interval for (a) Kodak Aero Super XX and (b) Kodak Super XX sheet film developed in SD-19A. Development times of (1) 18 min., (2) 13 min., and (3) 8 min. The speed values corresponding to development in D-19 for the same times are indicated by the horizontal dotted lines.

ments can not be made. Pressure marks are also greatly emphasized.

4. Speed.

Figure 5 shows the variation in the fractional gradient speeds[5] of Kodak Aero Super XX and Kodak Super XX sheet film, as the delay interval is varied, for different times of development in SD-19A. The limiting speed values for development in D-19, for the same times, are indicated by the horizontal dotted lines at the end of each curve. These values are exclusive of the "safety factor" of four included in practical exposure indices based on this criterion.[4,6]

The maximum gradient speed, for any given development time, is always obtained with the shortest possible delay interval. Theoretically, an increase in speed by a factor of five over the normal rating can be obtained with a development time of 13 minutes for Aero Super XX and 18 minutes for Super XX sheet film.

However, there is a serious drop in the resolution obtained under these conditions and speed measurements using a criterion based on the minimum exposure required to resolve detail of a given size[3,6] show that the increase in speed depends on the resolution level at which the speed is measured. At normally acceptable levels there is actually a loss of speed on this criterion and it is only at very low values of resolution that there is any substantial gain. Consequently, the use of SD-19A developer as a method of increasing film speeds offers advantages only when an extremely low standard of definition can be tolerated.

This rather contradictory result is due to the fact that the fractional gradient criterion is based only on considerations of tone rendering and neglects the structure of the image. It is, therefore, strictly applicable only when there is a close correspondence between the sensitometric characteristic curve and the resolution characteristic curve. This is normally the case but with development in SD-19A the resolving power can fall below the normally acceptable minimum before tone reproduction becomes unsatisfactory; the exposure is then determined by the minimum acceptable resolution.

5. Stability of the Solution.

The SD-19A working solution is very unstable and its activity falls off rapidly in the first few minutes after it is mixed. After this initial decay, there is little change in the characteristics of the developer for the next twenty-four hours. Early estimates of its working life[1] seem to have been based on this fact and appear to have overlooked the initial rapid decay.

On the other hand, the hydrazine stock solution is comparatively stable. Tests showed no detectable difference in the sensitometric characteristics of film strips processed with fresh hydrazine stock solution and with solution mixed the previous day. Apparently, rapid oxidation of the hydrazine takes place only in the alkaline working solution.

Even though the D-19 stock solution is normally quite stable, the rate of decay of the SD-19A working solution is influenced very much by the state of oxidation of the sulfite in it. Consequently, the D-19 solution used in this formula must be reasonably fresh.

Acknowledgments

The author wishes to express his thanks to Mr. P. D. Carman for his advice and assistance in this work.

References

1. H. A. Miller, R. W. Henn, and J. I. Crabtree P. S. A. Journal, Vol. 12, pp. 586, 692 (1946).
2. R. E. Stauffer, W. F. Smith, and A. P. H. Trivelli, J. Franklin Inst., Vol. 238, p. 291 (1944).
3. P. Hariharan, J. Opt. Soc. Am., Vol. 45, p. 60 (1955).
4. American Standards Association, "American Standard Method for Determining Photographic Speed and Exposure Index," Z38.2.1-1947.
5. L. A. Jones, J. Franklin Inst., Vol. 227, pp. 297, 497 (1939).
6. L. E. Howlett, Can. J. Research, Vol. 24A, p. 1 (1946).

Table I

FORMULA FOR KODAK SD-19A MAXIMUM EMULSION SPEED DEVELOPER

Stock Solution A	
0.2% solution Kodak Antifog No. 2 (6-nitrobenzimidazole-nitrate)	20.0 cc.
Hydrazine di-hydrochloride	1.6 gm.
Water to make	30.0 cc.
Stock Solution B	
Kodak D-19 developer	1.0 litre

To prepare the working solution, add 30 cc. of solution A to a litre of solution B.

Warning

Hydrazine di-hydrochloride is toxic and a skin irritant. It is advisable to use rubber gloves when working with this developer.

* American Standard Z38.2.1 (now superseded by ASA PH2.5-1954) specifically excludes aerial reconnaissance films from consideration. The applicability of the fractional gradient criterion to high contrast films has not been recognized by ASA. Ed.

THE E-2 EKTACHROME PROCESS: ITS VARIABLES AND THEIR CONTROL

A. G. Millikan* and N. H. Groet†

ABSTRACT

The structure of E-2 Ektachrome Film and its process are described. The effects of various process variables (time, temperature, agitation, wash rates, and chemical concentrations) and methods of their control at various processing volumes are discussed. Some of the problems encountered in chemical control are considered.

KODAK EKTACHROME Safety Color Film, E-135 and E-828, is a multilayer color film containing incorporated couplers and is designed for reversal processing by the E-2 Ektachrome Process. A schematic cross-section view of the film is shown in Figure 1a. The first layer coated on the film support is an antihalation layer which is decolorized during the bleach step of the process. A thin, insulating layer is then applied, followed by the red-sensitive emulsion layer which contains, in addition to the red-sensitized silver halide, a dispersion of a coupler capable of forming a cyan dye. A thin, gelatin interlayer is then applied for the purpose of preventing the products of development in one emulsion layer from affecting image formation in an adjacent emulsion layer. The next layer contains green-sensitized silver halide and a coupler capable of producing a magenta dye. A colloidal-silver filter layer then is coated over the green-sensitive layer. This filter layer serves the dual purpose of preventing blue light from reaching the underlying green- and red-sensitive layers and of reducing interlayer development effects. The top emulsion layer is blue-sensitive and contains a coupler producing a yellow dye. Over this is coated a gelatin layer serving as a protective overcoat.

The couplers used in this 35mm Ektachrome Film are of the oil-soluble type described by Mees.[1] Each coupler is incorporated in its emulsion layer in combination with a finely dispersed, oily carrier. Research during recent years has produced couplers with increased solubility in the carriers, with the result that more concentrated coupler solutions can be employed. This improvement has permitted the use of thinner layers than those in the older Ektachrome Sheet Film, a cross-sectioned view of which is shown for comparison in Figure 1b.

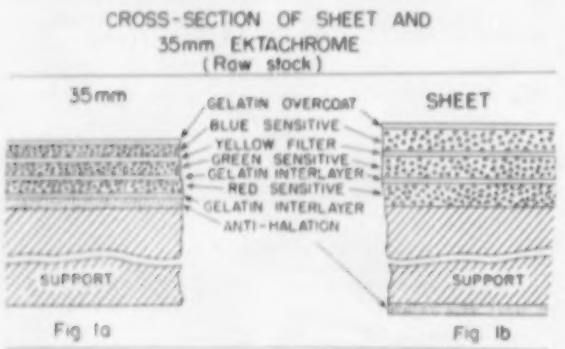


Fig. 1. Cross section diagrams of sheet and 35mm Ektachrome Film before processing.

* Color Technology Division, Eastman Kodak Company, Rochester, N. Y., and †Research Laboratories, Eastman Kodak Company, Rochester, N. Y. Presented at the PSA National Convention in Boston, Massachusetts, 5 October, 1955. Received 14 February, 1956.

Table I

E-2 EKTACHROME PROCESS SEQUENCE

Step	Solution or Procedure	Temperature in °F.	Time in Minutes
1	First developer	75	10
2	Rinse	73-77	1
3	Hardener	73-77	3-10
4	Reversal exposure		
5	Wash	73-77	3
6	Color developer	73-77	15
7	Wash	73-77	5
8	Clear	73-77	5
9	Rinse	73-77	1
10	Bleach	73-77	8
11	Rinse	73-77	1
12	Fix	73-77	3
13	Wash	73-77	8
14	Stabilizing	73-77	1
15	Dry		

Extensive investigations have been carried out to evolve processing formulas which will produce the optimum picture quality from films with the modified structure. The resulting film-process combination is to be regarded as a unit designed for best results, and neither the film nor the process can be used successfully with the other component from the older Ektachrome Sheet Film system.

The sequence of steps in the E-2 Ektachrome Process is given in Table I. The first bath is a negative developer similar in type to those used in conventional black-and-white work. This developer reduces to silver those silver halide grains in all of the emulsion layers which received exposure in the camera. A rinse is then given, followed by a treatment in a hardening bath which hardens the gelatin and stops the development reaction. After the film has been in the hardener for 3 minutes, the room lights may be turned on. The film is then re-

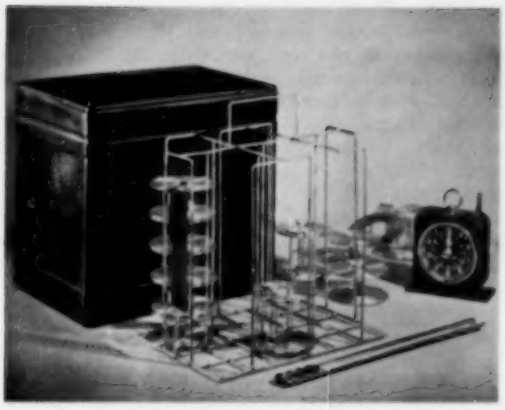


Fig. 2. Equipment for processing 30 rolls of 35mm Ektachrome Film on Nikor reels in a 3½-gallon tank.

exposed, and washed for 3 minutes. Enough light is used in re-exposure to insure that all of the silver halide remaining in the film after the first developer is fully exposed so that it will develop in the subsequent color developer.

The color-developer solution contains a developing agent whose oxidized form reacts with the couplers incorporated in the emulsion layers to produce dyes of the proper color at the right places. The color development is followed by a 5-minute wash, and then the film is treated for 5 minutes in a clearing bath which serves to remove the last traces of the color-developing agent from the film. After a short rinse, treatment in the ferricyanide bleach bath converts all the metallic silver in the film to silver halide. After another rinse, the silver halide is removed in a fixing bath. The final wash is followed by a stabilizing bath which protects the dyes in the film from some types of postprocess fading. The film may be dried following normal black-and-white procedures, except that care must be taken to avoid drying temperatures higher than 110 F.

It is to be emphasized that the E-2 Ektachrome Process has been designed specifically for the 35mm Ektachrome Film. Other color films, including the current Ektachrome Sheet Film, cannot be processed satisfactorily in the E-2 Process, and the 35mm Ektachrome Film will not give satisfactory quality if it is put through processes other than the E-2 Ektachrome Process. The only baths which are common to the E-2 Process and the Ektachrome Sheet Film (E-1) Process are the hardener, the clearing, and the fixing baths.

Processing Methods

The E-2 Ektachrome Process can be carried out in various ways, depending on the scale of the processing operation. Thus, the process can be used in equipment designed for handling single rolls, or in rack-and-tank or continuous-machine installations.

The Kodak Dayload Tank is representative of equipment used for processing single rolls of 35mm Ektachrome Film. With this tank, the 1-pint processing kit can be used, and six 20-exposure rolls can be processed before the solutions are exhausted.

A typical in-line 3½-gallon processing setup is illustrated in Figure 2. Thirty rolls of film, each on a Nikor reel, can be processed at one time, and the basket is provided with a holder for a control strip. With this arrangement, approximately 175 20-exposure rolls of 35mm Ektachrome Film can be processed before the solutions are exhausted.

A larger rack-and-tank system, the Kodak Rack and Tank Processor, Model 10E, is shown in Figure 3. The unit is capable of processing film at the rate of approximately 90 rolls per hour. If no replenishment is used, 500 20-exposure rolls can be processed before the solutions are exhausted. A nitrogen-burst system provides automatic agitation in all processing solutions.

For the processing of large volumes of film, continuous processing equipment would probably be the most desirable. However, at present, continuous processing equipment designed specifically for the E-2 Ektachrome Process is not commercially available.

Principles of Process Control

The underlying principles of control of color photographic processes have been described by Koerner.[2] Complete control requires both photographic measurements and chemical analyses, because neither one alone can give a complete evaluation of a color photographic process.

Control by chemical methods requires chemical analysis and adjustment of the many constituents of the processing solutions. If control by this technique is to be at all effective, it must be complete in its scope. Hence it requires the services of a skilled technician and

Fig. 3. Kodak Rack and Tank Processor, Model 10E, having a capacity of approximately 90 rolls per hour, with nitrogen-burst agitation of the solutions.

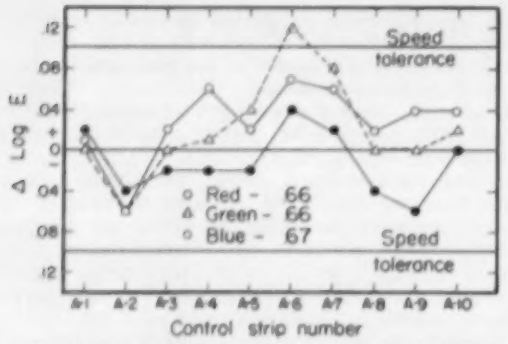


Fig. 4. Control chart on which data are entered from successive control strips to show the performance in relation to the standard and to control limits in both directions.

involves the use of expensive equipment. The cost of this operation is so high that it can be justified only for large-volume processing installations.

The need for extensive chemical control is reduced, to some extent, by the manufacture of processing and replenisher kits. The processor, by the use of such kits, is relieved of the burdens of testing and certifying batches of chemicals, accurate weighing of components, and analyzing and adjusting solutions. Meticulous care must be exercised, however, to follow the manufacturer's directions and recommendations for using the kits, since the process can be grossly affected by such factors as mixing procedures, storage conditions, and solution aging.

Photographic Control

The end result of the photographic process is a picture, and, in the final analysis, a process is termed a success or a failure according to the photographic quality obtained. However, a processor cannot judge his process on the basis of the quality of customers' films because, in any run, he is handling films representing many different emulsion batches and films of varying history with regard to age, storage conditions, and exposure. Hence, accurate photographic control of a process must be based upon the results obtained with control strips which carry a standardized exposure on a selected emulsion and which have received standard treatment throughout their history.

Some of the more important considerations involved in the preparation of such control strips are:

1. Exposure must be identical from strip to strip.
2. The film on which these exposures are made must be uniform throughout its length.
3. The film must be kept under conditions which render the latent image stable with time.
4. The conditions of exposure (duration and quality of light) must approximate closely those commonly used in practice.

If these requirements are to be met, much care and good equipment are needed. Since the processor is usually not equipped to produce his own control strips, the manufacturer supplies E-2 Ektachrome control strips. The strips are supplied in groups of twenty, each group containing a reference strip processed under standard conditions. The control strip from a given process may be compared either visually or, preferably, densitometrically, with the reference strip, to determine the direction and magnitude of departure from the standard. The unprocessed control strips must be stored at 0 F or lower to insure that changes in the strip resulting from latent-image keeping effects do not lead to erroneous results.

It is recommended that a color densitometer be used in evaluating the processed control strips, because this technique provides a more accurate evaluation of the quality of the process than can be obtained by visual judgment alone. From the densitometric readings, numerical values representing speed and color balance can easily be calculated. If these speed and color-balance values are plotted for each process against the standard values obtained from the reference strip, a continuing picture of the state of the process is obtained. Full information on techniques for using the E-2 Ektachrome Process control strips is available in the form of a Kodak Processing Control Kit for the E-2 Ektachrome Process.

The nature of color photographic materials and their processes is such that a certain amount of chance variation in results will be observed. Therefore, a control chart, as illustrated in Figure 4, should include control limits as well as the standard levels. Variation about standard but within these limits is normal. Corrective action should not be considered until the results, when plotted, are outside the control limits or until the average results, when plotted, are consistently near a limit.

Process Variables

Successful operation of the E-2 Ektachrome Process depends upon the precise balancing of the rates of many different chemical reactions. Those parameters which influence the rates at which the various chemical reactions proceed give rise to variations in the final results. In general, the variables of importance in the E-2 Process can be separated into two classes, physical and chemical.

The important physical variables of time, temperature, and agitation must be controlled carefully in those steps of the process in which the chemical reactions are not carried to completion. (Reversal exposure is another important physical variable.)

Time—Time of development in the first developer is of particular importance since the rates at which the three emulsion layers develop are not equal. The desired end result (proper speed and color balance) is obtained only if the development is stopped when each of the three layers has been developed to the proper point. The standard time of first development for the E-2 Process is 10 minutes; off-standard results will be obtained if this time is not maintained to within ± 15 seconds. As the first development time is increased, the effective film speed increases, the color balance becomes magenta-blue, and the maximum density decreases as a result of increased negative fog. As the time of first development is decreased, the speed decreases, the color balance shifts toward the yellow-green, the contrast decreases, and the highlight density increases.

A greater time tolerance, ±1 minute, is permissible in the color developer because the chemical reactions occurring in this solution go essentially to completion in

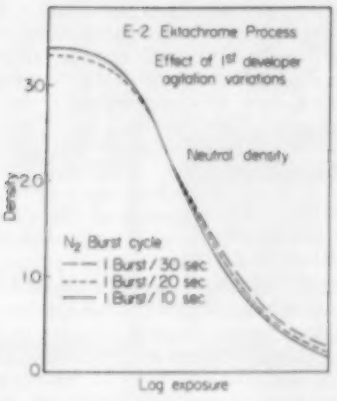


Fig. 5. First developer agitation variations.

the recommended time. It is to be noted that this time may become more critical as the solutions approach exhaustion.

The recommended time for the wash following the clearing bath is not less than 30 seconds nor more than 90 seconds. This recommendation should be followed closely. In order to obtain complete bleaching of the silver in the bleach bath, it is a necessary condition that some hypo be present in the film when it is put into the bleach. If the wash time is prolonged, incomplete bleaching of the silver will result and the colors in the processed film will be degraded. If the time in the wash is too short, the hypo concentration will increase in the bleach bath and shorten its useful life.

The effects of variations in time in all of the solutions are listed in Table II.

Temperature—The rate of development varies rapidly with changes in temperature, and hence the temperature of the first developer in the E-2 Process must be maintained within narrow limits. If the desired results are to be obtained, this first developer temperature must be maintained at 75 F ± 1/3°. If the temperature of this solution increases to 75 1/3 F, the speed increases approximately one-fifth stop, and the balance becomes magenta-blue. If the temperature drops to 74 1/3 F, the speed decreases approximately one-fifth stop, and the color balance shifts in the yellow-green direction. The temperature of the other solutions is less critical, and the recommended range, 73 F–77 F, gives adequate results. The wash temperatures may vary to a greater extent, except for the rinse following the first developer. This rinse bath does not act as an effective development stop bath, and consequently first development continues at a reduced rate during this wash. Hence the temperature of this wash should be maintained between 73 F and 77 F. Very wide changes in the other wash temperatures are not advisable, since there is danger of reticulation if high wash temperatures are used.

Agitation—Agitation serves to keep the developer at the film surface relatively constant in activity by removing the oxidized developer and replacing it with fresh solution. If the rate of agitation is too high, the effect is similar to that obtained by prolonged development. If the level of agitation is too low, underdevelopment will result. In the E-2 Ektachrome Process, the first developer is more sensitive to changes in agitation levels than are the other solutions. Increased agitation tends to increase speed to some extent, but more importantly, it increases the toe contrast. The E-2 Process, like that for Ektachrome Sheet Film, was designed to give optimum results with lift-and-drain-type agitation. Hand agitation does not, however, lend itself well to large-volume processing techniques. Excellent results have been obtained using gaseous-burst agitation with a burst-cycle of 1-second duration repeated once every 15 seconds. The effect of changing the level of agitation in the first developer is shown in Figure 5. It is seen that higher burst rates lead to increased toe contrast.

Reversal Exposure—The purpose of the reversal exposure is to make developable all of the silver halide which remains in the film following the first development. If the minimum light requirement is met during this exposure, the color quality of the light source and the duration of exposure are not critical. Tungsten bulbs, photoflood lamps, fluorescent tubes, and tungsten Lumaline tubes have all been used successfully. If insufficient reversal exposure is given, the maximum density and contrast, measured with green light, decrease. Figure 6 illustrates the results obtained if the reversal exposure is omitted entirely.

Replenishment—In any photographic process, best results are obtained when all the chemical constituents of

Table II

EFFECT OF TIME VARIATIONS IN THE E-2 EKTACHROME PROCESS

Solution	Standard Time in Minutes	Effect of Increasing Time from Below Normal to Above Normal	Tolerance
First developer	10	Increased speed and toe contrast; color balance shifts toward magenta-blue	± 15 sec. (critical)
Rinse	1	Decreased density throughout scale	± 20 sec. (critical)
Hardener	3–10	Shorter time may cause reticulation	
Wash	3		± 1 min.
Color developer	15	Slightly more magenta in balance and increased yellow stain	± 1 min.
Wash	5	1) slightly lower minimum density 2) more yellow mid-scale balance 3) more magenta shoulder	± 1 min.
Clear	5	Color balance shifts toward blue; increased yellow stain	± 1 min. Omission of this bath produces a heavy red stain
Wash	1	Greater density throughout	± 30 sec.
Bleach	6	Increased stain (shortened time leads to silver retention)	± 2 min.
Wash	1		± 5 min.
Fix	3	Reduced density; balance shifts toward cyan	−30 sec.
Wash	8		+2 min.

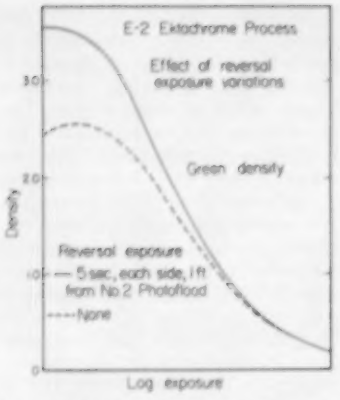


Fig. 6. Effect of reversal exposure variations.

the processing baths are held at a specified concentration. This ideal condition can be met, however, only by using fresh solutions for each roll of film, a practice which is not economically feasible. A satisfactory compromise method of operation is reached in either of two ways: (1) The processing solutions are used until the process control limits are reached; at this point, the solutions are discarded and new solutions are mixed. (2) A given area of film is processed per unit volume of solution, and then a portion of the tank solution is discarded and replaced with replenisher solution. The former method is recommended for use with the standard processing kits, and is suitable for small-volume processing. With the latter batch-replenishment system, the amount of film which can be processed in a given set of solutions is approximately three times that possible with the standard kit procedure.

Mixing—Improper mixing of solutions can cause serious difficulty. The E-2 processing solutions are carefully designed to have as much reserve capacity as possible. As a consequence, some of the chemicals are present in the solutions at concentrations close to their solubility limits. The mixing instructions, which state that each mix should be started at full volume, must be followed explicitly. The need for mixing at full volume is particularly important in the color developer; if the liquid component of this solution is not thoroughly dissolved prior to the addition of the other chemicals, an off-standard process will almost inevitably result. It is recommended that mixing be done in tanks other than those used for processing so that any undissolved chemicals do not lodge in the corners of the processing tanks. If a common mixing tank is used, it is recommended that the solutions be mixed in the same sequence that they are used in the process, and that the mixing tank be thoroughly rinsed after the mixing of each solution. Contamination of one solution by another should be avoided. Particular care should be used to insure that the developer solutions are not contaminated by the clearing or fixing baths.

The foregoing brief discussion indicates that with the large number of variables involved in color photographic processes, recognition and control of each of these variables must be achieved in order to establish a stable standard process. When this condition is attained, any careful processor can obtain excellent quality with the E-2 Ektachrome Process.

References

1. C. E. K. Mees, "The Theory of the Photographic Process," Revised Ed., p. 598, The Macmillan Co., New York (1954).
2. A. M. Koerner, J. Soc. Mot. Pict. and Television Engrs., Vol. 63, pp. 225–230, Dec., 1954.

PROJECTION LAMPS EASILY IDENTIFIED BY NEW AMERICAN STANDARD CODE

S. David Hoffman* and R. P. Woolery†

AN AMERICAN STANDARD Code has been established for designating and identifying projection lamps used in photographic and other equipment. Manufacturers of these lamps offer a multiplicity of types with the same wattage rating. This practice has created confusion for lamp users. For example, there are more than a dozen separate and distinct models of "300-watt projection lamps." (See Figure 1.) The illustration shows fourteen models having different bases, different bulb sizes, and some have "black tops."

* American Standards Association, Incorporated, 70 East 45th Street, New York 17, New York.
† Photographic Lamp Department, General Electric Company, Nela Park, Cleveland, Ohio. Received 28 March, 1956.

It is apparent that several lamps shown in Figure 1 appear identical to the layman. Yet all these lamps are marked with the same label! The lamp manufacturer brands all of them with the same data: "300W, 120V, Projection, Base Down." Even when a buyer walks into a retail store with the old lamp in his hand and requests "One like this. . . .", he still has to depend upon the alertness, knowledge and integrity of the seller to supply the proper replacement lamp.

Lamp manufacturers have recognized the need for a better identification system for a long time. Early in 1955, using the facilities of the American Standards Association, General Electric Company initiated cooperative discussions among the four manufacturers

Fig. 2. Containers for projection lamps have been marked as shown at left. Following the new Code, the containers will bear three-letter identification, such as the DGS designation shown at the right. The identification formerly used by manufacturer is included on box for interim period but will be discarded later. The insets above show the corresponding markings which are stamped on the lamp envelopes themselves under the old and the new system.

producing motion picture or slide projector lamps concerning the possibilities of standardization. The purpose was to develop a system for specifically labelling and identifying each type of projection lamp, sound reproducer lamp, and other related types of lamps intended for photographic use.

At the first meeting it was agreed that a good lamp identification system should fulfill the following requirements:

1. Provide easy identification, by labelling the lamp prominently with a simple designation which gives complete ordering information.

2. Be adaptable to present manufacturing methods with no increase in production problems.

3. Have flexibility so as to be capable of encompassing all existing lamps of this category, and leaving ample room for any which may be produced in the foreseeable future.

Though general agreement was arrived at on the above points, a great deal of discussion centered around one question. Should the lamp designation symbols employ a meaningful code, or should the code have no significance without the use of a key sheet? The staff of ASA was particularly vigorous in proposing that a non-meaningful code be used. It has been their experience through application of several of these systems that wherever symbols, letters, or numbers are used which tell something about the product, the system soon becomes so complicated as to be unworkable, or nearly so.

Some of the manufacturers advanced very strong arguments in favor of having a system at least partially significant. This was based on their feeling that at least the wattage of the lamp should be indicated on the lamp itself. The arguments counter to this proposition were based on the fact that time and again designation systems employing a meaningful code are broken down, resulting in designations that are longer and much more confusing than those without meaning other than for pure identification. The real base of this difficulty is that while voltage and wattage may be vital today, no one can foresee that these same lamp characteristics will be of equal importance in the future. In particular, it was noted that the more significance a system has the more difficult it becomes for the administering organization to make assignments, and the more possibility there is of conflicts between manufacturers who may possibly believe that they held a pre-emptive right, because of commercial and sales considerations, to a particular designation.

This argument was finally resolved and the following agreed upon:

1. A non-significant symbol will be marked on the lamp to designate completely each individual type.

2. This designation will be composed of three letters of the alphabet. However, the letters I, O, Q, and U will not be used in order to avoid possible conflict and ambiguity. (In this regard, American Telephone and Telegraph Company's experience has shown it is best to discard these four letters for any stamping or marking purposes, because of the possibility of their being confused with others.) This system allows a total of 10,658 combinations.

3. Wattage, voltage, and burning position may be indicated on the bulb at the discretion of the manufacturer concerned.

4. This system will be administered through the American Standards Association, which will assign the codes, and keep complete records of the operation.

An administrative problem was anticipated when a lamp which is already coded is improved in some way that changes a specification. Here it was decided that the existing code designation of the lamp should be used for the improved lamp, providing the new lamp is interchangeable with the old in equipment. Similarly, when different manufacturers offer slightly different de-

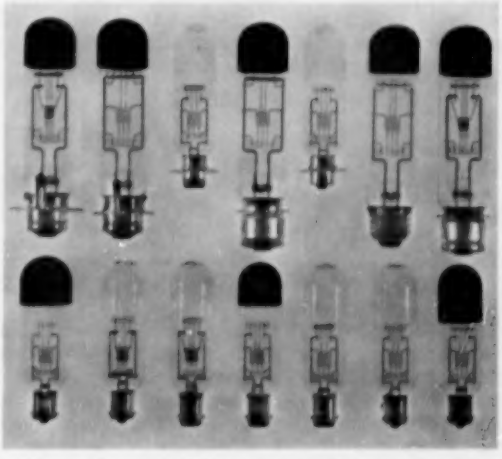


Fig. 1. Fourteen different types of "300-watt projection lamps" in different sizes and styles are not interchangeable but today all bear the same marking.

signs in lamps which each feels are commercially interchangeable, the same code will be used, even though certain requirements of the specification may be at variance.

Accordingly, a standard has been written which includes an explanation of the code, the procedure to be followed by ASA in assigning and recording the code, a sample of the lamp code request form which is filed by the manufacturer at the time he brings out a new product, and material to be used by the ASA staff in determining general classifications of bulbs, bases, and filaments.

In their administration of this system the American Standards Association will adopt a punched card system which uses one card for each lamp code assigned and recorded. The holes are arranged around the edge of the card, which make the card mechanically articulate. The use of these cards and associated equipment will greatly simplify administration, and make it possible to determine in short order whether the lamp is coded by characteristics and is already recorded, or if not, whether there is an existing lamp of somewhat similar characteristics.

The fruition of this work will be observed in the next few months. Purchasers of projection lamps will find these new three-letter codes on the carton and on the lamp. See Figure 2. From that time on, when a lamp burns out, all the customer has to do is go to wherever he buys his lamps, and ask for a new lamp by the code letters, much as he would ask for a radio tube, and he will get the proper replacement for his equipment.

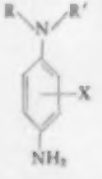
It is understood that photographic equipment manufacturers are planning to incorporate, on the name plates of their products, codes for the proper lamps to be used. This will certainly help the user.

American Standard Code for the Designation of Photo Lamps, C78.370-1956, is one more example of the benefits to the consumer which accrue from industry cooperation sponsored by the American Standards Association.

PROPERTIES OF *p*-PHENYLENEDIAMINE COLOR-DEVELOPING AGENTS

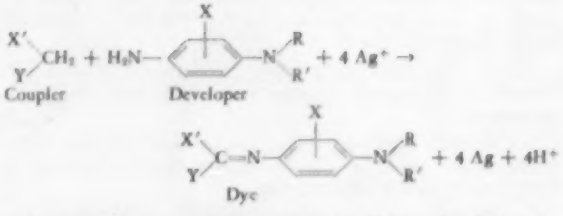
John R. Thirtle*

WHILE COLOR DEVELOPERS are similar to black-and-white developers in reducing exposed silver halide grains at a rate faster than that for unexposed grains, they differ in that their oxidation products are used for dye formation.[1] Practical color developers must reduce the silver halide at a reasonable rate and produce oxidation products stable enough to reach and to react with coupler molecules, forming dyes which have the desired properties. Severe restrictions are thus imposed on the types of compounds which are suitable, and color-developing agents are almost exclusively N,N-dialkyl-*p*-phenylenediamines, having the following structure:

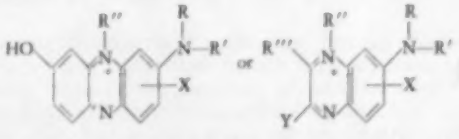


in which R and R′ are alkyl or substituted alkyl; and X = H or other substituent.

Dyes produced in color photographic materials such as Kodachrome, Ektachrome, Kodacolor, Agfacolor, Ansco Color, etc., are formed by the reaction of oxidized developer with compounds containing active methylene or methine groups. The over-all reaction can be written as:



A secondary reaction may occur if the developer or coupler is substituted with an arylamino or alkylamino group in a suitable position, giving so-called azine dyes of the general structure,[3]



Studies have been made which relate structural variations in color-developing agents to *electrochemical properties*, *development rates*, *autoxidation rates*, *coupling efficiencies*, and *allergenic toxicity*.[2,4,5] The free energy change involved in the oxidation of a developing agent can be determined by measurement of the polarographic half-wave potential, $E_{1/2}$, of the developing agent. The greater the tendency of the agent to lose electrons, the greater will be the free energy of the process and the more positive will be the oxidation half-wave potential of the developing agent. Thus, in general, the more active developing agents will have the more positive

* Research Laboratories, Eastman Kodak Company, Rochester 4, New York. Received 27 January, 1956.

Table I

EFFECT OF CHANGES IN R AND R′ ON THE HALF-WAVE POTENTIALS AND DEVELOPMENT RATES OF N,N-DIALKYL-*p*-PHENYLENEDIAMINES

R	R′	$E_{1/2}$(mv) *vs.* H Electrode at pH 11	Dev. Rate[a] ($min.^{-1}$)
CH_3	CH_3	−235	0.30
C_2H_5	C_2H_5	−222	.44
C_3H_7	C_3H_7	−204	.53
R = CH_3	R′ = Variable		
CH_3	CH_3	−235	.30
CH_3	C_2H_5	−231	.34
CH_3	n-C_3H_7	−225	.44
R = C_2H_5	R′ = Variable		
C_2H_5	CH_3	−231	.34
C_2H_5	C_2H_5	−222	.44
C_2H_5	n-C_3H_7	−217	.58
R = C_2H_5	R′ = Substituted Alkyl		
C_2H_5	CH_2CONH_2	−290	.037
C_2H_5	$CH_2CH_2OCH_3$	−253	
C_2H_5	$CH_2CH_2OC_2H_5$	−242	.15
C_2H_5	CH_3[b]	−231	.34
C_2H_5	C_2H_5[b]	−222	.44
C_2H_5	$CH_2CH_2NHSO_2CH_3$	−219[c]	18[d]
C_2H_5	CH_2CH_2OH	−206[e]	42
C_2H_5	$CH_2CH_2NH_2$	−204[e]	50

[a] Reciprocal of time required after induction period to reach a density 0.2 above fog density.
[b] Reference compounds.
[c] Electron-attracting inductive effect of $NHSO_2CH_3$ is probably overcome by dissociation at pH 11 to $N(\ )SO_2CH_3$.
[d] Low value probably due to low diffusivity.
[e] Anomalous.

half-wave potentials and, indeed, the relation between half-wave potentials and a logarithmic plot of development rates is linear within satisfactorily narrow limits.

Table I shows the effect of changes in R and R′ on the half-wave potentials and development rates of N,N-dialkyl-*p*-phenylenediamines. The compounds in each section are listed in the order of increasing potentials and rates, an order which is in general agreement with increasing electron-donating inductive effects[6] in R and R′ and therefore an increasing ability of the molecule to lose electrons.

At the semiquinone stage of oxidation of the developing agent, the resonance hybrid must contain certain contributing structures which are quinonoid in nature. These structures require that R, R′, N, and the ring all lie in one plane. If such configurations are inhibited by steric hindrance, formation of the semiquinone will be inhibited and the half-wave potential and development rate will be smaller than in the absence of steric effects. Molecular models show that the hydrogen atoms in the 2- and 6-positions inhibit coplanarity in the oxidized forms of the N-(*p*-aminophenyl) derivatives of morpholine, piperazine, and piperidine. On the other hand, N-(*p*-aminophenyl)pyrrolidine is less hindered in the oxidized form than is the semiquinone of the parent compound, N,N-diethyl-*p*-phenylenediamine. Table II shows the striking results of steric effects on the measurements for these compounds.

On the other hand, if R, R′, and N are coplanar or nearly so in the reduced form, the transition to the semiquinone is facilitated. By cyclizing R or R′ or both with the *ortho*-positions in the ring, a nearly planar molecule is formed, even in the unoxidized form of the compound, and half-wave potentials and development rates show marked increases over the parent compounds.

Changes in X in the 3-position (Table IV) produce *major* variations in half-wave potentials and development rates. The measurements are in agreement with those expected by virtue of the known inductive and mesomeric effects exerted by substituents on the benzene ring. Exceptions are to be noted where X is $NHSO_2CH_3$ or OH which can be explained on the basis of dissociation at pH 11, and where X is $N(CH_3)_2$, which exhibits steric interference with the *p*-NH_2 group.

The strong inductive and mesomeric effects noted for substituents in the 3-position should also apply to N,N-

Table II

RESULTS OF STERIC EFFECTS ON THE MEASUREMENTS FOR N-(*p*-AMINOPHENYL) DERIVATIVES OF MORPHOLINE, PIPERAZINE, AND PIPERIDINE

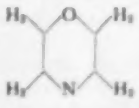
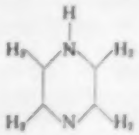
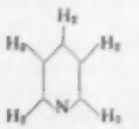
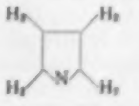
	$E_{1/2}$(mv)	Dev. Rate ($min.^{-1}$)
	−315	0.0012
	−304	0.13
	−254	.054
(N,N-Diethyl-*p*-phenylenediamine	−222	.44)
	−202	.83

Table III

EFFECT OF CYCLIZATION OF R OR R′ OR BOTH WITH THE *ORTHO*-POSITIONS IN THE RING

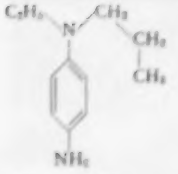
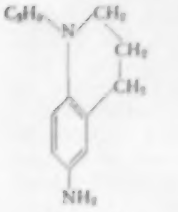
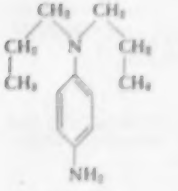
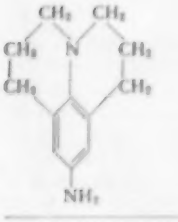
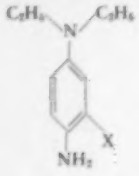
	$E_{1/2}$(mv)	Dev. Rate (min^{-1})
	−217	0.58
	−182	1.42
	−204	0.53
	−142	2.5

Table IV

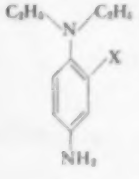
EFFECT OF VARIOUS SUBSTITUENTS IN THE 3-POSITION OF COLOR DEVELOPERS



X	$E_{1/2}$(mv)	Dev. Rate (min^{-1})
Cl	−271	0.091
H	−222	.44
C_2H_5	−203	...
$NHCOCH_3$	−199	.31
CH_3	−190	.80
OCH_3	−159	.27
OC_6H_5	−153	.71
$N(CH_3)_2$	−110	2.2
$NHSO_2CH_3$	− 81	1.7
NH_2	− 58	3.3
NHC_2H_5	− 17	2.5
OH	+ 62	2.5

Table V

EFFECT OF VARIOUS SUBSTITUENTS IN THE 2-POSITION OF COLOR DEVELOPERS



X	$E_{1/2}$(mv)	Dev. Rate (min^{-1})
$NHCOCH_3$	−390	0.0014
CH_3	−341	.0038
NH_2	−305	.029
OCH_3	−287	.032
H	−222	.44

dialkyl-*p*-phenylenediamines substituted in the 2-position (Table V). They do, but steric hindrance with the N-alkyl groups is so great that the semiquinone forms with difficulty and half-wave potentials and development rates are greatly reduced.

Autoxidation rates have been determined for some N,N-dialkyl-*p*-phenylenediamines. These rates are higher the more positive the half-wave potential, but a more precise mathematical relationship has not been reported.[5]

Coupling efficiency shows little variation in a series of compounds differing widely in developing activity.[5] Thus, about the same coupling efficiency is observed for N-(4-amino-3-methylphenyl)-morpholine ($E_{1/2}$-298, development rate 0.01) as for 4-amino-N,N-diethyl-3-ethylaminoaniline ($E_{1/2}$-17, development rate 2.5).

Allergenic toxicity, which produces skin disorders like those caused by poison ivy, increases with developing activity, with certain exceptions. Compounds having substituents which reduce lipid solubility and/or promote keratin-affinity cause a lower dermatitic response.[7]

References

1. C. E. K. Mees, "The Theory of the Photographic Process," Revised edition, The Macmillan Co., New York, N. Y. (1954); Fischer, U. S. Pat. 1,102,028 (1914); J. S. Friedman, "History of Color Photography," American Photographic Publishing Co., Boston, Mass. (1944); P. W. Vittum and A. Weissberger, J. Phot. Sci., 2, p. 81 (1954).
2. V. Tulagin, U. S. Pat. 2,414,491 (1947); W. A. Schmidt and V. Tulagin, U. S. Pat. 2,486,440 (1949); etc.
3. R. L. Bent, J. C. Dessloch, F. C. Duennebier, D. W. Fassett, D. B. Glass, T. H. James, D. B. Julian, W. R. Ruby, J. M. Snell, J. H. Sterner, J. R. Thirtle, P. W. Vittum, and A. Weissberger, J. Am. Chem. Soc., Vol. 73, p. 3100 (1951).
4. D. B. Julian and W. R. Ruby, J. Am. Chem. Soc., Vol. 72, p. 4719 (1950).
5. J. E. La Valle, D. B. Glass, and A. Weissberger, J. Am. Chem. Soc., Vol. 70, p. 2223 (1948).
6. A. E. Remick, "Electronic Interpretations of Organic Chemistry," 2nd edition, J. Wiley and Sons, Inc., New York, N. Y. (1949); Johnson, in Gilman, "Organic Chemistry," 2nd edition, J. Wiley and Sons, Inc., New York, N. Y. (1943).
7. A. Weissberger, U. S. Pat. 2,193,015 (1940).

THIOUREA AS AN ACCELERATOR OF THE SOLUTION AND DEVELOPMENT OF SILVER HALIDE GRAINS

T. H. James and W. Vanselow*

ABSTRACT

Thiourea markedly accelerates development by an acid iron-Sequestrene† developer. It also increases the rate of solution of silver halide grains in an acid developer. These accelerations are produced by as little as 0.00001 *M* thiourea. The effects can be obtained by prebathing the film in an acid thiourea solution and washing out the excess thiourea before transferring the film to the developer solution. Derivatives of thiourea produce a similar, though usually smaller, effect. Thiourea eliminates the induction period in development of a motion-picture positive emulsion and of an experimental emulsion which produces predominantly surface latent image, but the densities and gamma obtained by prolonged development in the presence of thiourea are no greater than those obtained in its absence. The action of the thiourea resembles that of the quaternary salt accelerators, but a much larger amount of quaternary salt is required to produce the same acceleration. Thiourea also promotes development in acid systems in an unsensitized silver bromide emulsion of a latent image which either does not develop in a surface developer, or requires an excessively long time for development.

The acceleration of development by thiourea does not depend on the increased rate of solution of the silver halide, since the acceleration depends upon the nature of the developer. Amidol and 1-phenyl-3-pyrazolidinone develop without an induction period in acid solution, and thiourea retards development by these agents. The acceleration of development by the ferrous-Sequestrene solution may have a common cause with the increased rate of solution, however. The mechanism of the acceleration is discussed on the basis of the charge effect and of displacement of gelatin from the silver halide surface.

Thiourea and many of its derivatives are well known as chemical sensitizers for photographic emulsions. These compounds under proper conditions can produce other effects of interest to photographic theory which are quite independent of the sensitizing action. The present paper compares the action of thiourea as an accelerator of development and of solution of silver halide grains in a photographic emulsion.

The action of thiourea as a development accelerator has been observed before. Rawling,[1] in an investigation of the Waterhouse reversal,[2] showed that photographic plates could be bathed in an allylthiourea solution and subsequently developed in an acid ferrous oxalate developer without serious fog formation. If the plates treated with allylthiourea were bathed in sodium hydroxide solution before development, so that silver sulfide was formed by reaction of silver ion with the allylthiourea, the plates developed a heavy fog. Rawling makes the incidental observation that the allylthiourea treatment alone caused development to start more quickly than it did in the absence of such treatment. Lüppo-Cramer[3] observed that allylthiourea accelerated development under some conditions but not under others. His work will be discussed later in this paper.

No direct observations have been reported on the effect of thiourea or its derivatives on the rate of solution of silver halide grains, but Oyama and Futaki[4] showed that the addition of small amounts of allylthiourea to a silver chloride–polyvinyl alcohol emulsion caused a marked increase in the rate of growth of the silver chloride grains during physical ripening. N-octadecyl-N′-allylthiourea and N,N′-dioctadecylthiourea were even more effective.

* Research Laboratories, Eastman Kodak Company, Rochester 4, New York. Communication No. 1781 from the Kodak Research Laboratories. Received 1 March, 1956.

† Sequestrene is a trade-mark for ethylenediamine tetraacetic acid.

Rate of Solution Studies

The technique described in a previous publication[5] can be used to determine to what extent small amounts of thiourea and its derivatives can influence the *rate* of solution of silver halide grains in a coated emulsion. The method depends upon the fact that the grains can be mixed with a Carey-Lea-type silver sol (prepared by dextrose reduction of silver nitrate in the presence of gelatin) before coating, and subsequently coated without becoming fogged. The method depends also upon finding a developer which will reduce silver ions as fast as they arrive at the sol nuclei. The Metol–ascorbic acid developer of pH 10.3 used in the previous work is not suitable for use with thiourea because the latter in alkaline solution reacts with silver bromide to form silver sulfide. However, the sulfiding reaction between thiourea and silver bromide becomes negligible when the pH is sufficiently low, and a ferrous sulfate–Sequestrene solution can be used as developer at this low pH.

The pH used for most of the work with thiourea was 4.8. No sulfiding reaction between the thiourea and silver bromide could be detected at this pH, even after contact for several hours. Calculations based on previous data indicate that no significant reaction would occur during the times involved in the present experiments. It has been shown[6,7] that the rate of reaction between allylthiourea and silver bromide varies as the square of the hydroxyl-ion concentration over the pH range 6.5—7.9 in the presence of excess bromide ion. If this relation holds to pH 4.8, the calculated rate of reaction for allylthiourea adsorbed as a monolayer on silver bromide[7] is 0.000004 percent per minute in the presence of 0.0001 *M* potassium bromide and the absence of gelatin. An emulsion grain of 1 square micron surface area will contain approximately 2×10^8 molecules of allylthiourea at monolayer coverage, and the reaction rate in terms of molecules per grain is one molecule

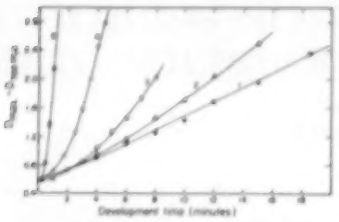


Fig. 1. Pure AgBr emulsion: Iron–Sequestrene developer + 1 g of KBr per liter; pH 4.8 buffered; 19.8 C: Curve 1, no thiourea; Curve 2, 0.00001 *M*; Curve 3, 0.00003 *M*; Curve 4, 0.00010 *M*; Curve 5, 0.0005 *M* thiourea.

reacting every 12 minutes. At the bromide-ion concentration of 0.0083 *M* used in much of the present work, and with the grains coated by gelatin, the actual rate of reaction is probably smaller by at least two orders of magnitude.

The developer had the following composition:

Ferrous sulfate (hydrated)	3.0 g
Sequestrene (tetrasodium salt)	3.0 g
1.0 *N* Sulfuric acid	1.0 cc
Acetate buffer	50.0 cc
Water to make	360.0 cc

The acetate buffer was composed of 0.4 *M* sodium acetate and 0.2 *M* acetic acid. The solution was made up by dissolving the ferrous sulfate in water made acid by the sulfuric acid, and then adding the buffer to form one component solution of 260 cc total volume. The Sequestrene was dissolved in water to make 100 cc. The two solutions were then deaerated separately in the nitrogen developing-apparatus and subsequently mixed in this apparatus to form the completed developer. The pH of the solution at 20 C was 4.8. The developer was used either without added bromide or with 1.0 g potassium bromide per liter (0.0083 *M*).

The emulsion used for the rate-of-solution work was a pure silver bromide material which had not been chemically sensitized. The coated emulsion contained 2.03 g of silver sol per mole of silver bromide. The experimental procedure followed that described[5] previously. The rate of physical development of the sol particles is a measure of the rate of solution of the silver halide when the developer is active enough to reduce the silver ions as fast as they arrive at the silver particles. The ferrous–Sequestrene developer fulfills this requirement for the materials used in the present experiments. The rate of physical development was measured in terms of the rate of increase of density at the absorption maximum, where density is proportional to the mass of silver. A small correction for fog was made by subtracting the density measured at 700 mμ from the density measured at the maximum.

The effect of thiourea concentrations varying from 0.00001 *M* to 0.0005 *M* on the rate of growth of density is shown in Figure 1 for a solution containing 1.0 g of potassium bromide per liter. The relation between density and time is linear in the absence of thiourea, and hence the rate of increase in density is essentially constant. The slope of this line represents the rate of solution of the silver bromide in the acid bromide solution at pH 4.8. When thiourea is present in the solution, the density–time relation is not linear during the first few minutes, and the rate of change of density increases with increasing time of development. Eventually, the curve becomes linear.

Figure 2 shows that the same general effect is observed when the solution contains no potassium bromide. The density–time curve in the absence of thiourea is linear, whereas the curves obtained in the presence of thiourea show an "induction period." If the film is prebathed for 30 minutes in a solution of the buffer at pH 4.8, then transferred to the developer containing thiourea, the density–time curve is essentially the same as that obtained without the prebathing. If, however, the film is prebathed in a thiourea solution buffered at pH 4.8 but containing no developing agent, and is subsequently transferred to the developer which contains the same amount of thiourea, the density–time curve is linear. The prebathing treatment eliminates the induction period. Curve 5 in Figure 2 shows the results of the prebathing treatment in a 0.00003 *M* thiourea solution.

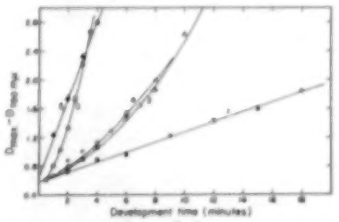


Fig. 2. Pure AgBr emulsion: Iron–Sequestrene developer (no KBr) at pH 4.8; 19.9 C: Curve 1, no addition; Curve 2, 0.00003 *M* thiourea; Curve 3, 0.00010 *M* thiourea; Curve 4, prebathed 30 minutes in buffer, 0.00003 *M* thiourea in developer; Curve 5, prebathed 30 minutes in 0.00003 *M* thiourea, 0.00003 *M* thiourea in developer.

The prebathing experiments were repeated with a developer to which 1.0 g of potassium bromide per liter had been added. The results were substantially the same as those obtained in the absence of bromide. Moreover, no significant change occurred when the prebathing in thiourea was followed by a period of washing in slightly acidulated running water before development. When, however, the prebathed, washed film was soaked in a sodium carbonate solution for 10 minutes, rewashed, then transferred to the thiourea-containing developer, the effect of the thiourea prebath was largely eliminated. The prebathed strip showed a rate-of-density growth which was initially greater than that of the untreated film, but the initial increase lasted no more than a minute. The remainder of the density–time curve was parallel to that of the untreated strip. Hence, the silver sulfide formed by reaction of the adsorbed thiourea and silver bromide at the high pH of the sodium carbonate solution does not produce a permanent increase in the rate of solution of the silver halide analogous to that produced by the unreacted thiourea. Development of the film which had been given the sodium carbonate treatment could not be carried very far before an objectionable amount of neutral fog density appeared, probably caused by development of silver sulfide fog centers.

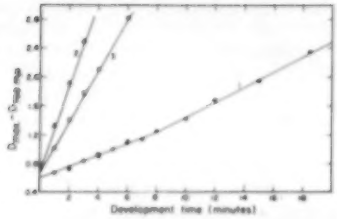


Fig. 3. Pure AgBr emulsion: Iron–Sequestrene developer + 1 g of KBr per liter; pH 4.8 buffered; 19.7 C: Curve 1, no pretreatment; Curve 2, prebathed in 0.0001 *M* 1,3-di-*n*-butylthiourea solution for 30 minutes; Curve 3, prebathed in 0.00001 *M* 1,3-di-*n*-butylthiourea solution for 3 hours.

In another set of experiments, the film was prebathed in the acid 0.00003 *M* thiourea solution, washed in acidulated running water, and then developed in a solution which did not contain thiourea. The washing treatment should eliminate any thiourea remaining in the film after the prebathing except that held adsorbed by the silver halide. The increase in density during the first few minutes in the developer which contained no thiourea was substantially the same as that previously obtained with pretreated film immersed in a developer which contained 0.00003 *M* thiourea. Hence, the adsorbed layer of thiourea promotes the solution of the silver bromide, and the rate of solution in the early stages is as great when the developer contains no thiourea as it is when the developer contains 0.00003 *M* thiourea. The results of similar experiments with 1,3-di-*n*-butylthiourea are illustrated in Figure 3. The prebath solutions in these experiments contained 0.00001 *M* and and 0.0001 *M* 1,3-di-*n*-butylthiourea. The film was thoroughly washed in running water after the prebathing, and then developed in a solution which contained no thiourea. The prebathing caused a large increase in the rate-of-density growth. The higher concentration of the thiourea produced the larger increase, but the tenfold change in concentration produced only a twofold increase in rate.

Some experiments were carried out with a silver bromide emulsion prepared with polyvinyl alcohol instead of gelatin. The effect of thiourea on the rate of growth of density in this emulsion is shown in Figure 4. The rate of solution of the silver halide, both in the presence and in the absence of thiourea, is slower in the polyvinyl alcohol medium than in the gelatin medium, but the relative effect of the thiourea is about the same.

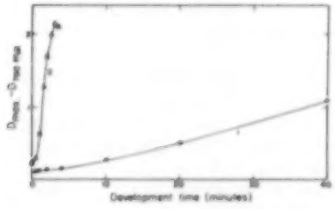


Fig. 4. Motion-picture, fine-grain emulsion in polyvinyl alcohol medium: Iron–Sequestrene developer + 1 g of KBr per liter; pH 4.7 buffered; 20.8 C: Curve 1, no addition; Curve 2, 0.0005 *M* thiourea.

Table I

EFFECT OF THIOUREA AND ITS DERIVATIVES ON THE RATE OF SOLUTION OF SILVER BROMIDE, AS SHOWN BY THE RATE OF DENSITY INCREASE IN A DEVELOPER CONTAINING 1.0g KBr/LITER pH 4.8.

Addition (0.0001 *M*)	Temp., °C.	ΔD/Min.
None	19.8	0.072
1,3-Diacetyl thiourea	19.7	0.131
Acetylthiourea	19.8	0.163
Tetramethylthiourea	19.8	0.236
1,3-Di-*n*-butylthiourea	19.7	0.296
1,3-Diethylthiourea	19.5	0.65
n-Butylthiourea	19.5	0.67
Thiourea	19.8	0.79
Allylthiourea	19.7	0.82

The effect of various substituted thioureas on the rate of solution of pure silver bromide grains in a gelatin emulsion was tested. The thioureas were added to the developer at a concentration of 0.00010 *M*. Each of the density–time curves has an induction period. The effectiveness of each derivative in promoting the rate of solution of silver bromide is indicated by the data given in Table I, where the slopes of the straight-line portions of the density–time curves are listed. Allyl-, 1,3-diethyl-, *n*-butyl-, and ethylenethiourea are nearly as effective in promoting solution as the unsubstituted compound. The acetyl and 1,3-diacetyl derivatives are much less effective, and the 1,3-di-*n*-butyl and tetramethyl derivatives are intermediate in effectiveness. These differences may be associated with differences in the adsorption characteristics of the various thioureas. The acetyl and diacetyl derivatives are much less effective in displacing adsorbed merocyanine dyes from silver bromide, and hence are less strongly adsorbed by silver bromide, than allylthiourea and thiourea itself.

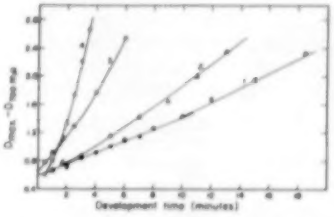


Fig. 5. Pure AgBr emulsion: Iron–Sequestrene developer + 1 g of KBr per liter; pH 4.8 buffered; 19.7 C: Curve 1, no addition; Curve 2, 0.0001 *M* sodium thiosulfate + 0.022 *M* sodium sulfite; Curve 3, 0.0084 *M* α-picolinium-β-phenylethyl ion; Curve 4, 0.0001 *M* thiourea.

The quaternary α-picolinium-β-phenylethyl ion increases the rate of solution of silver bromide when present in the developer. It is of interest to compare the effect of this agent with that of thiourea, particularly in view of the parallel influence which the two exert on development, as shown in the next section. Figure 5 illustrates the density–time curves obtained in the experiments on the rate of solution for a developer which contained 1 g of potassium bromide per liter or the equivalent amount of bromide ion. A curve illustrating the effect of thiosulfate on the rate of solution is also included. Thiourea is much more effective in promoting

solution than an equivalent amount of thiosulfate, and is more effective than the much larger concentration of quaternary salt used. Other experiments showed that prebathing the emulsion in a solution of the quaternary salt followed by development in a solution which did not contain the quaternary salt produced only a temporary increase in the rate of solution. Film which had been washed and film which had not been washed after the pretreatment both showed an initial increase of density greater than that obtained with the untreated control, but the rate-of-density formation after about 1 minute became substantially equal to that of the control. Similar results were obtained when the developer contained no bromide.

Effect on the Rate of Development

Lüppo-Cramer[7] in 1934 observed that development by a dilute alkaline solution of hydroquinone was accelerated if the exposed emulsion was first bathed for 1.5 minutes in a 1:100,000 solution of allylthiourea and then washed briefly before development. The induction-period characteristic of hydroquinone development was eliminated by the allylthiourea treatment. The acceleration diminished with increasing time of development, and eventually disappeared. A similar acceleration was obtained for development by *p*-hydroxyphenylglycine and by acid ferrous oxalate restrained by potassium bromide. Little or no effect was observed with rapid developers which showed little or no induction period. Loening, Sutherns, and Bourne[8] observed an apparent sensitization of silver bromide sols by thiourea in acid solution, but concluded that it was a development effect because the addition of the thiourea after exposure produced an effect similar to that obtained by the addition before exposure.

Some experiments were carried out on the effect of thiourea on the development of several different types of photographic emulsions. The emulsions used were: (1) a high-contrast, commercial, motion-picture positive material, (2) an experimental sulfur-sensitized emulsion which gave predominantly surface latent image, and (3)

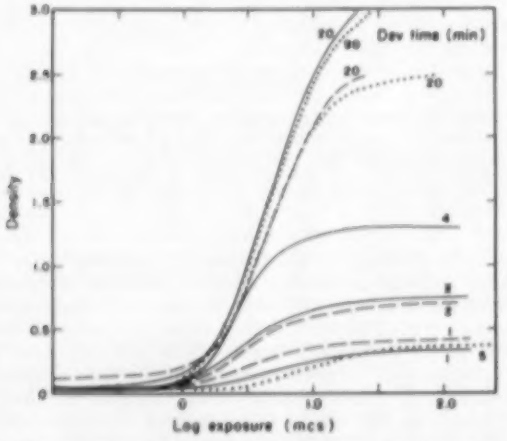


Fig. 6. Emulsion (1): Iron–Sequestrene developer + equivalent of 1 g of KBr per liter; pH 4.8; 20 C: Curves ... no addition; — 0.0005 *M* thiourea; ——— 0.0084 *M* α-picolinium-β-phenylethyl ion.

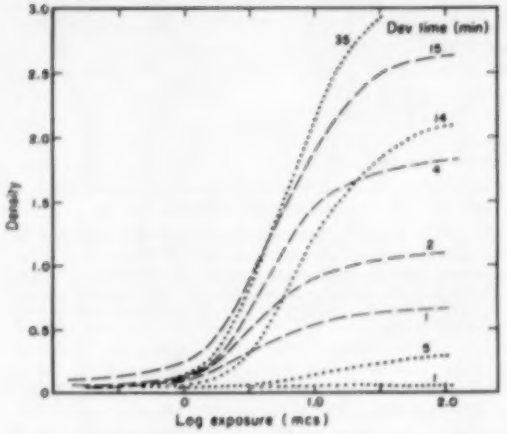


Fig. 7. Emulsion (2): Iron–Sequestrene developer + 1 g of KBr per liter; pH 4.8; 20 C: Curves: ... no addition; — 0.0005 *M* thiourea.

an experimental unsensitized pure bromide material which produced more internal than surface latent image.[9] The ferrous–Sequestrene developer buffered at pH 4.8 and with the addition of 1 g potassium bromide per liter was used at 20.0 C for most of the tests.

Thiourea markedly accelerated development of the commercial motion-picture positive emulsion. This acceleration is illustrated by the characteristic curves plotted in Figure 6. The dotted curves represent development in the simple developer. The broken curves represent development in a developer of the same composition with the addition of 0.0005 *M* thiourea (0.038 g per liter). The addition of 0.0084 *M* α-picolinium-β-phenylethyl bromide (solid curves) to the simple developer produced roughly the same acceleration as the 0.0005 *M* thiourea. The potassium bromide was omitted from the developer containing the quaternary salt because the bromide of the quaternary salt was equivalent to 1 g of potassium bromide per liter. Thiourea produced a similar increase in the rate of development of Emulsion (2), as shown in Figure 7.

The acceleration produced by both the quaternary ion and the thiourea was most pronounced in the early stages of development of Emulsions (1) and (2). Both agents eliminated the induction period. Eventually, the densities obtained in the absence of accelerator equalled those obtained in its presence. The thiourea caused some increase in the fog level for the longer times of development, whereas the quaternary salt did not. Tests made on strips of film which had been bleached in a 0.3 percent potassium ferricyanide solution to destroy surface latent image before development showed that the thiourea-containing solution developed only a trace of internal image in 65 minutes with Emulsion (1) and none with Emulsion (2). Hence, the increase in the rate-of-density formation in the early stages of development of the unbleached emulsion must be attributed to an acceleration of the development of the surface latent image.

Thiourea accelerated development of the emulsion which forms a considerable amount of internal image, but the thiourea has an additional action on this emulsion.

Figure 8 shows the characteristic curves obtained with Emulsion (3) by development in the simple ferrous–Sequestrene solution and by development in the presence of thiourea and the quaternary ion. The developer which contained the thiourea produced much higher densities than could be obtained even by prolonged development in the simple solution. The thiourea caused some development of internal latent image on sensitometer strips which had been bleached for 5 minutes in the 0.3 percent ferricyanide solution, but the first trace of development appeared only after 10 to 15 minutes had elapsed, and the amount of internal-image development was not nearly enough to account for the increased development of the unbleached strips. The quaternary ion also increased the developed density beyond that obtained in the simple solution, but was not as effective as the thiourea in this respect. The quaternary ion did not cause development of internal image on the silver bromide emulsion.

The thiourea does not need to be in the developer to accelerate development. The rate of growth of density when the film was prebathed for 30 minutes in 0.0001 *M* thiourea at pH 4.8 and then washed to remove the excess before development in a thiourea-free solution was nearly as great as it was when the 0.0001 *M* thiourea was added directly to the developer. The 1,3-di-*n*-butyl-thiourea was much less effective than thiourea itself in promoting development, but it made no difference whether this substance was added to the developer or was used as a prebath followed by washing.

Tests also were made with acid solutions of Amidol and 1-phenyl-3-pyrazolidinone as developers. Both of these solutions develop without an induction period. The commercial, motion-picture emulsion was used in these tests. Figure 9 illustrates the results obtained with a developer composed of 14 g Amidol per liter, buffered at pH 5.55. In contrast to the results obtained with the ferrous–Sequestrene developer, thiourea actually retards development by the Amidol solution. Similar results were obtained with a solution of 0.8 g of

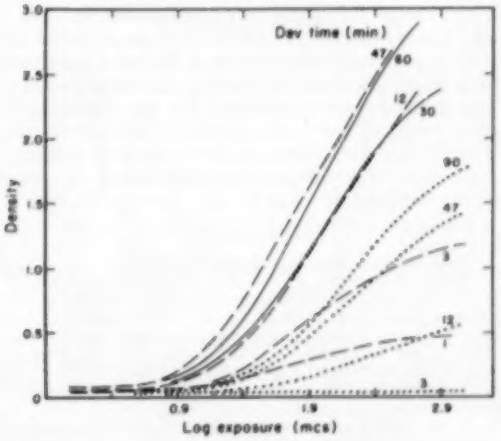


Fig. 8. Emulsion (3): Iron–Sequestrene developer + equivalent of 1 g of KBr per liter; pH 4.8; 20 C: Curves: ... no addition; --- 0.0005 *M* thiourea; ——— 0.0084 *M* α-picolinium-β-phenylethyl ion.

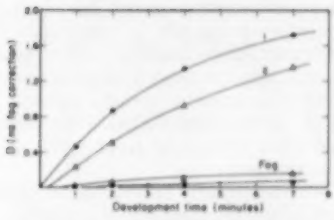


Fig. 9. Emulsion (1): Densities at log *E* = 2.0; 20.0 C: Curve 1 ●●, Amidol developer at pH 5.55; Curve 2 △△ Amidol developer + 0.0005 *M* thiourea at pH 5.60.

1-phenyl-3-pyrazolidinone per liter at pH 5.9. The latter solution developed at only about one twenty-fifth the rate of development by the Amidol. The solution which contained 0.0005 *M* thiourea developed more slowly than the one which did not contain thiourea, and produced a colored image which showed the characteristics of physical development. A considerable amount of dichroic fog formed also. When the film was prebathed in 0.0001 *M* acid thiourea solution for 30 minutes and washed before being transferred to the thiourea-free developer, development once more proceeded at a reduced rate, but the image color was normal and the rate-of-fog formation also was reduced. On the other hand, thiourea promoted development of internal latent image by these developers when the unsensitized emulsion was used, although it still retarded the initial development of the surface latent image.

Discussion

The present experiments show that thiourea can accelerate development by the acid ferrous–Sequestrene solution in two ways. The thiourea causes a marked acceleration of the development of surface latent image, as shown by the results with the commercial, motion-picture positive emulsion and especially with the experimental sulfur-sensitized emulsion which contains negligible amounts of internal latent image. The acceleration of development of these emulsions is confined to short times, and disappears by the time 20 minutes has elapsed. The maximum density is not increased. The unsensitized pure bromide emulsion shows quite different behavior. The thiourea accelerates development of this emulsion from the start, but the densities obtained in the presence of thiourea greatly exceed those obtained in its absence even on prolonged development. The thiourea not only accelerates development of purely surface latent image in this emulsion, but promotes development of internal latent image as well.

The acceleration of surface latent image is not associated with an increase in the rate of solution of the silver halide. It depends upon the specific nature of the developer. The acceleration is marked when the ferrous–Sequestrene developer is used, but the thiourea actually retards development by Amidol and 1-phenyl-3-pyrazolidinone. The acceleration is qualitatively like that produced by the quaternary salts, although quantitatively 0.0005 *M* thiourea is equivalent to 0.0084 *M* α-picolinium-β-phenylethyl ion. On the other hand,

the promotion of internal-image development depends upon the increase in the rate of solution. Thiourea at 0.0005 *M* concentration causes a greater increase in the rate of solution than 0.0084 *M* α-picolinium-β-phenylethyl ion, and also causes a greater increase in the rate of development of the unsensitized emulsions which are characterized by a relatively large ratio of internal to surface latent image.

The rate of development of the unsensitized Emulsion (3) in the presence of thiourea is considerably greater than would be obtained by a simple addition of the rate of surface-image development and the rate of internal-image development, as determined experimentally with the bleached film. Two explanations can be suggested. The experimentally determined rate of development of internal image may be too low because the net rate of solution of the silver halide grains is increased when silver on which the silver ions can develop is situated nearby. Surface-image development in the unbleached strips would supply such silver and hence would increase the rate of solution of grains which were nearby, but which did not contain surface image. The experimentally determined rate of development of internal image may be too low because the bleach destroyed some internal image which lay very close to the grain surface. Loening, Sutherns, and Bourne[8] have postulated the existence of "two types of internal image, viz., the true internal image, which is buried in the lattice of the silver halide and is not accessible to reagents such as developers or oxidizing agents, and another internal image. . . .situated in the top layer of the lattice, and therefore accessible to reagents like the thioureas." They propose to call the latter a "subsurface image." Such an image might be destroyed by the ferricyanide bleach.

The basic cause of acceleration of development of surface latent image by thiourea may be essentially the same as the cause of the increase in rate of solution. Both the rate of development and of solution are increased by a layer of *adsorbed* thiourea. Hence, the thiourea has in some way changed the surface of the silver halide grains to one which dissolves more rapidly than the original surface, and is developed more rapidly by the ferrous–Sequestrene solution. One explanation depends upon the charge effect. Experiments by LuValle[10] show that about 10^{-6} *M* thiourea is sufficient to shift the zeta-potential of a silver bromide sol from −60 mv to a substantially zero or slightly positive value at pH 4.0. The depression in the negative charge of the silver halide surface would facilitate the approach of the negatively charged, ferrous–Sequestrene ions to the grain surface and probably would promote adsorption of the ions by that surface. Hence, the action of thiourea in eliminating the induction period and accelerating development of surface latent image by the ferrous–Sequestrene can be explained on the basis of the charge effect. Development by Amidol and by 1-phenyl-3-pyrazolidinone should not be accelerated by thiourea according to this view, and the retardation of development observed can be explained on the basis of competitive adsorption.[11] Lüppo-Cramer's observations[3] likewise are in line with the charge-effect explanation, since hydroquinone and *p*-hydroxyphenylglycine both act as negative ions with a double charge in alkaline solution.

Evans, Hedges, and Mitchell[12] have suggested that the quaternary ions may be able to displace gelatin from the silver halide surface, and such action could lead to acceleration of development. Thiourea, which is much more strongly adsorbed than the quaternary ions, likewise may displace gelatin, since the thiourea can displace cyanine dyes which West, Carroll, and Whitcomb[13] showed will displace gelatin. However, the failure of either thiourea or the quaternary ions to accelerate development by Amidol and 1-phenyl-3-pyrazolidinone is less easily explained on the basis of displacement of gelatin than on the basis of a change in the surface charge of the grain.

The charge effect also may account for the increased rate of solution of the silver halide which contains an adsorbed layer of thiourea. We have shown previously that adsorption of certain rhodanine derivatives is accompanied by displacement of bromide ions from the surface. If adsorption of thiourea likewise causes a displacement of bromide ions, this displacement and the resulting decrease in negative charge could facilitate the passage into solution of silver ions which are not a part of the adsorption complex. As the silver halide passes into solution from the surface layer of the grain, the adsorbed thiourea layer would re-form on the fresh surface. The quaternary ion is not so strongly or rapidly adsorbed by the silver bromide and does not displace bromide ions from the surface. Indeed, electrostatic attraction between the bromide ions and the positively charged quaternary ions is an important factor in the adsorption of the latter. The depression of surface charge brought about by adsorption of the quaternary ion could still facilitate passage of silver ions into solution. The quaternary-ion monolayer becomes disrupted by this process which weakens the adsorption of the bromide ions, and the quaternary ion may also pass into solution. The adsorption layer may be re-formed effectively only if a substantial concentration of quaternary ions exists in the solution. An alternate hypothesis depending upon the displacement of gelatin by thiourea and the quaternary ions cannot be ruled out as an explanation for the increased rate of solution.

When thiourea is present in the developer solution, particularly at the highest concentrations used in this work, the formation of soluble complexes with silver ions also may promote solution. Thiourea is known to form soluble complexes with silver ions in acid solution. For example, Fyfe[14] reports that the precipitate initially formed when thiourea is added to acid silver nitrate solution redissolves when the mole ratio of thiourea to silver is 3:1. The dissociation constant of the $AgTu_3^+$ complex is about 10^{-13} at 25 C.

References

1. S. O. Rawling, Phot. J., Vol. 66, p. 343 (1926).
2. J. Waterhouse, Brit. J. Phot., Vol. 37, pp. 601, 613 (1890).
3. H. Lüppo-Cramer, Phot. Korr., Vol. 70, p. 145 (1934).
4. Y. Oyama and K. Futaki, J. Soc. Sci. Phot. Japan, Vol. 16, p. 39 (1953); Y. Oyama, Proc. Roy. Phot. Soc. Centenary Intern. Confer. on the Science and Applications of Photography, London, Sept. 19–25, 1953, R. S. Schultze (editor), Roy. Phot. Soc., 1955, p. 37.
5. T. H. James and W. Vanselow, Phot. Sci. and Technique, (2) Vol. 2, p. 135 (1955).
6. B. H. Carroll and D. Hubbard, Bur. Standards J. Research, Vol. 12, p. 329 (1934).
7. T. H. James and W. Vanselow, J. Phys. Chem., Vol. 57, p. 725 (1953).
8. E. E. Loening, E. A. Sutherns, and B. P. Bourne, J. Phot. Sci., Vol. 2, p. 160 (1954).

9. *Cf.* work on image distribution in unsensitized and sensitized emulsions by W. G. Lowe, J. E. Jones, and H. E. Roberts, "Fundamental Mechanisms of Photographic Sensitivity," J. W. Mitchell (editor), Butterworths Scientific Publications, Ltd., London, 1951, p. 112, and by A. Hautot and H. Sauvenier, Science et inds. phot., (2) Vol. 24, p. 257 (1953).
10. J. E. LuValle, private communication.
11. T. H. James, and W. Vanselow, J. Phys. Chem., Vol. 58, p. 894 (1954).
12. T. Evans, J. M. Hedges, and J. W. Mitchell, J. Phot. Sci., Vol. 3, p. 73 (1955).
13. W. West, B. H. Carroll, and D. L. Whitcomb, J. Phot. Sci., Vol. 1, p. 145 (1953).
14. W. S. Fyfe, J. Chem. Soc. (London), 1955, p. 1032.

SOME IMPROVEMENTS ON THE DAGUERREOTYPE PROCESS OF PHOTOGRAPHY

O. Sherwood Poppe*

After the government of France purchased Daguerre's process in 1839, the book *Historique et description des procedes du daguerreotype et du diorama* was published in Paris that same year. Another account, written by Louis Jacques Maude Daguerre, was translated into English by J. F. Frazer[1] and published in the United States. The following description of Daguerre's method is taken from Frazer's article.

Daguerre divides his process into five operations: The first consists in polishing and cleaning the plate, so as to render it fit for receiving the sensitive coating. The second, in applying this coating.

The third operation submits the plate thus prepared, to the action of the light in the camera obscura, in order to receive upon it the picture from nature.

The fourth operation causes this picture to appear; it not being visible when first taken from the camera obscura.

Finally, the fifth has for its object, the removal of the sensitive coating which would continue to be modified by the light, and would tend necessarily to destroy the impression altogether.

First Operation

The plate is polished by the following method: sprinkle with pumice previously tied in a small muslin sack and rub gently with a circular motion with cotton soaked in olive oil. Repeat this process several times, but Daguerre warns "The mortar employed for pulverizing the pumice should be neither of cast-iron nor of copper, but of agate" and, of course, the pumice should be quite fine so the plate will not become scratched during the polishing.

After the polishing operation the plate is rubbed gently with "nitric acid diluted with water in the proportion of one part of acid, to sixteen parts of distilled water" using only a small amount of acid, enough to wet the central portion of a cotton plug. The acid is removed by gentle rubbing with several fresh cotton plugs until the plate is "covered with a regular veil over all its extent."

The plate is again rubbed with pumice, and after this operation heated with high heat of a spirit-lamp which "is passed backwards and forwards along the under surface of the plate, so close that the flame may be broken upon it." A whitish coating will form on the plate after about five minutes, and then the plate should be removed, polished again by pumice and cotton, treated three more times with the nitric acid solution, each time rubbing the plate completely dry (always with a circular motion) with frequent changes of cotton plugs. The polisher should take special precautions so that the portions of the cotton touched by the fingers will not touch the silver surface because "the transpiration would cause blurs upon the drawing. The humid vapour of the breath must also be avoided, as well as drops of saliva."

Second Operation

The silver plate is attached to a frame and placed in a light-tight iodizing box containing a dish of iodine crystals covered with a piece of gauze stretched above the dish. In a dark room "into which no light penetrates excepting through a door which is left a little open" the plate is allowed to remain in the box until "the surface of the silver is covered with a perfect coating of a golden yellow colour." No heat is applied to the iodine and it is important that the interior of the box be at the same temperature of the exterior otherwise moisture may condense on the plate which would be "very injurious to the results." The longer the box is used the better it becomes, for the wood of the box absorbs the iodine and this vapor "tending always to disengage itself" will cause the silver plate to become coated more quickly.

The time for this iodizing operation to attain the " golden yellow coat cannot be accurately fixed (it may vary from five to thirty minutes, rarely more, unless it be very cold)" and it is quite important to examine the plate from time to time and to remove it as soon as it reaches the required color, for "if it be left too long, this golden coating will pass to a violet color, which must be avoided since the coating is then not so sensitive to light." If by incorrect timing the plate becomes violet due to over exposure to the iodine vapors, the polishing operation must be repeated to remove the iodide coating and the plate refumed with iodine.

* 1682 Lower Grand Avenue, Piedmont 11, California. An abstract from a thesis presented to the Graduate Division, Reed College, Portland, Oregon, August 1955, in partial fulfillment of the requirements for the degree Master of Arts. Received 30 November, 1955.

Third Operation

The plate is exposed in the camera and "the most favourable time is from 7 until 3 o'clock; and, at Paris, what we obtain in three or four minutes in June or July, will require 5 or 6 minutes in May or August, 7 or 8 in April or September, and so on, in the same proportion as we advance in the season." It is important neither to over-expose nor under-expose for the image produced would not be perfect. Daguerre advises that "if we have failed in the first impression by withdrawing it too soon, or leaving it too long, we commence another immediately with almost a certainty of success; it is of advantage even, to make some experimental impressions in order to acquire practice."

After exposure in the camera the plate should be developed within an hour's time by means of the fourth step.

Fourth Operation

The developing apparatus consists of a pan of mercury (Daguerre advises to use about two pounds) enclosed in a box and arranged so that the mercury can be heated by a spirit lamp. The plate is inclined at a 45° angle with the sensitive iodized surface toward the mercury so that it can be viewed at intervals during the development through a window in the box. The exposed plate is placed within the box, the lid closed, and the mercury heated to 60 Centigrade; the image appears slowly and its progress may be watched by using a candle. By the time the temperature of the mercury has fallen to 45 C the plate should be removed and examined in existing room light. The plate's image should be fixed as described in the fifth step even though the "impression may be preserved in this state, for several months, without undergoing any alteration, provided it be not often examined in a strong light."

Fifth Operation

To remove the sensitive iodide coating unaffected by light and the mercury development treatment, the plate is fixed by either of two methods; Daguerre recommends the second. In the first method the plate is rinsed in distilled water, soaked in a saturated solution of salt heated almost to boiling until the yellow iodide coating is removed from the plate, and then rinsed several times in hot distilled water and allowed to dry. The second method consists of rinsing the plate in distilled water, soaking it in a dilute solution of "hyposulfite of soda" until the iodide is removed, and then rinsing and drying it as in the first method.

The impressions should not be touched or rubbed otherwise the image will come off. Daguerre recommends that "to preserve the impressions, they must be put under glass and cemented in; they are then unalterable, even in the sun."

Improvements of the Original Process

The Daguerreotype process was not perfect. One of the greatest difficulties was in obtaining silver plates of the required quality; often the available plates possessed marked imperfections. The plates were either obtained from France or the United States; Goode[3] observed that "American plates are exceedingly imperfect." In the 1840's some silvered plates were prepared by rolling together under great pressure sheets of copper and silver and had to be obtained commercially. Some photographers, however, made their own silver surfaces in a manner described by Goode: "A piece of brass, or of planished copper—brass is preferred—is perfectly polished and its surface made perfectly clean. A solution of nitrate of silver, so weak that the silver is precipitated slowly, and of a brownish color, on the brass, is laid uniformly over it, 'at least three times' with a camel's hair pencil. After each application of the nitrate, the plate should be rubbed gently in one direction, with moistened bitartrate of potassa, applied with buff. This coat of silver receives a fine polish from peroxide of iron and buff. Proofs are said to have been taken on it, comparable with those obtained on French plates."

Experiments with Daguerre's Procedure

Producing an acceptable Daguerreotype which even remotely resembles an image of some object is not an easy task to accomplish because of the number of variables involved. If the silver plate does not have the required polish, the image after development appears clouded, if it appears at all. An uneven coating of iodine vapor or a coating which is too thick or too thin makes it impossible to "guess" the proper exposure resulting in a solarized, blurred or extremely faint image. If during development, the mercury is raised to too high a temperature, large globules of mercury condense on the entire surface of the silver plate making the image indistinct and lacking in contrast. If the mercury is not heated to a sufficient temperature, the image appears so slowly that the operator becomes impatient, heating the mercury too much and thus an acceptable image is again not produced.

In order to overcome these difficulties, the following variations of Daguerre's original process were devised.

Preliminary experiments were carried out utilizing several different silver cyanide complex and silver iodide complex electroplating baths[3] with a copper sheet as the anode. Electroplating had to be abandoned because great difficulty was encountered in polishing the silver even when using a buffing wheel and a fine grade of jeweler's rouge. Also, the polishing operations took a great deal of time. Pits, smudges, and scratches almost always appeared in the finished plate. It was decided to produce a silvered surface on a material which itself was extremely smooth and would require little if any polishing. Glass appeared to be the answer.

Several methods of producing mirrors on glass supports were investigated and it was decided that the mirrors which best suited Daguerreotyping were produced by the Rochelle salt process as outlined by Hiscox.[4] It was discovered that the glass surfaces to be used to produce *perfect* mirrors must be absolutely free from grease, finger prints, dust specks, etc. Ordinary 3.25" × 4" lantern slide plates were cleaned according to the method which follows.

Cleaning the Glass Surfaces

Each piece of glass and the treating equipment were soaked in regular cleaning solution composed of concen-

trated sulfuric acid C.P. and potassium dichromate, and after this treatment the glass ware was thoroughly rinsed to insure the removal (as completely as possible) of any ions which may have become absorbed during cleaning. Where water was used as the solvent for chemicals, ordinary Portland, Oregon, tap water was used except in the case of the silvering solutions where the tap water was first passed through an ion-exchange resin column.

Before replating the glass plates which had previously been used for Daguerreotype plates, the silver and mercury on the glass were removed by soaking the plates in concentrated nitric acid until all visible traces of the silver and mercury disappeared; after this the plates were rinsed in water, rubbed with paper towels, and then soaked in 1 molar sodium hydroxide solution. It was hoped that this treatment would successfully remove all traces of silver and mercury from the glass surface, and evidently it did, though no chemical tests were made. Perfect mirrors were made on the glass surfaces thus treated.

The plates were next cleaned with gray Lava soap, being especially careful to rub over the entire surface with paper towels. The plates were next carried through the following cleansing steps: (a) rinsed under flowing water, (b) cleaned in a solution of Joy, (c) rinsed thoroughly in flowing water again, and (d) transferred and stored until needed in a solution made up from one part cleaning solution to sixty parts water.

From the dilute cleaning solution one plate was placed into a previously cleaned 600 ml beaker, the transfer being completed with the fingers making this the last time that any of the plates came into contact with the fingers until the silvered plates were dry. This beaker was filled with cleaning solution, and the plate was soaked for ten minutes. The cleaning solution was then decanted into another 600 ml beaker containing another glass plate. The plate just removed from the cleaning solution was washed in the beaker with three successive changes of water being careful not to allow the water to flow directly from the tap on to the side of the glass plate which was to be mirrored. In all following steps this washing procedure was strictly adhered to, for its was found that by washing in any other manner streaks frequently appeared on the finished mirror, and, of course, streaks were *not* desired.

With the washing of the plate accomplished, a solution of 0.01 molar salicylic acid[5] was poured into the beaker containing the glass plate and allowed to remain in contact for ten minutes. Since the mirroring time required ten minutes, a ten minute cleaning time seemed a good standard and thus kept things rolling assembly-line style. After the salicylic acid treatment, the glass plate was rinsed in its beaker three times and then transferred to a stannous chloride solution[6], approximately 0.1 molar.

The stannous cloride stock solution was prepared by boiling together 238 grams of stannous chloride and water and then adding sufficient hydrochloric acid to dissolve the hydrolyzed stannous chloride. The entire volume was adjusted to 200 ml by evaporation or addition of water as was necessary. Experience showed that if the molarity of the stannous chloride solution in contact with the glass plate were reduced to 0.05 molar and the glass plate treated subsequently in hydrochloric acid, the mirrored surface did not appear for about seven minutes and even so it was characterized by surface irregularities in plating. Omitting the hydrochloric acid rinse after the 0.05 molar stannous chloride treatment permitted the silver to plate out fairly rapidly, but streaks appeared which were probably due to non-uniform removal of the hydrolyzed stannous chloride. For this reason a 0.1 molar stannous chloride solution was used and followed directly without washing by a 1 molar hydrochloric acid bath.

After the hydrochloric acid treatment the plate was rinsed twice in cold water, twice in hot water, once more in cold water, and twice in de-ionized water.

At times the plates were left to soak in the de-ionized water until needed, and at other times the plates were transferred directly to the silvering solutions.

Silvering Solutions. Hiscox's silvering solutions, converted to metric units, were made in the following manner. *Solution I, Reducing Solution:* 946 ml de-ionized water was heated to boiling to which 3.1 grams of silver nitrate was added and after this dissolved 3.1 grams Rochelle salt were added. The mixture boiled for seven minutes and then was filtered twice while still hot. *Solution II, Silvering Solution:* in 473 ml de-ionized water 4.9 grams of silver nitrate were dissolved and sufficient ammonium hydroxide was added drop by drop until the precipitate formed by the addition of the ammonium hydroxide *just* cleared. The solution was diluted to 946 ml by adding de-ionized water.

The cleaned glass plate was transferred to a beaker containing the *Reducing Solution* at 60 C and allowed to remain for about one minute. The plate was then placed in the silvering pan which consisted of a 25¢ plastic sandwich box, the transfer being accomplished without having the fingers touch the glass plate. Twenty milliliters of the *Silvering Solution* were flowed over the surface of the glass plate being careful not to pour *Silvering Solution* directly from the graduated cylinder on to the glass surface, but rather pouring the solution into one side of the silvering pan and then tilting the pan to allow the solution to flow over the glass evenly.

As a brownish deposit began to appear on the glass surface, usually within ten seconds, 20 ml of *Reducing Solution* (equal in volume to the silvering solution) was flowed into the silvering pan in the same manner as described above. The entire solution was rocked gently throughout the duration of the plating process of three minutes or until specks of a black flocculent precipitate appeared in the solution.

The used solution was poured into dilute hydrochloric and nitric acids to prevent the formation of silver fulminate[7], and the plating operation was repeated two more times.

If at any time during the plating operation, the silver appeared to be plating out unevenly, or if blemishes or pock marks appeared on the silver surface, the mirroring of that plate was suspended and the plate recleaned to be mirrored again.

To be positive that the *Silvering Solution* contained the excess of silver necessary to the plating operation, a small amount of silver nitrate solution was kept handy and from time to time as the plating proceeded too slowly,

three or four drops of the silver nitrate solution were added to the *Silvering Solution*. It was found that if too much silver nitrate were added, the mirror plated out from the silvering bath appeared golden in color and this golden color did not disappear completely upon drying; in addition the golden mirrors did not produce excellent Daguerreotypes. It was essential to have the proper amount of excess silver.

The completely silvered plate was rinsed in water and then by means of a glass fork removed from the silvering tray and placed on paper towels to dry. Some plates were dried in the air by allowing air currents in the room to evaporate the water and at other times by using warm air from a hair drier. No difference was noticed in the finished Daugerreotypes when either method was used though one small streak did appear close to the bottom of the plates dried with air currents, a procedure which always leaves the last droplet of water at the bottom.

The mirrored plates were stored in an air-tight container until ready for iodine sensitization.

Sensitization

By the historical method the plates were sensitized by iodine in the form of vapor. Fuming by iodine produced uneven sensitization which resulted in poorly defined pictures, and, too, fuming exposed the writer to iodine vapors. In an effort to produce more evenly sensitized plates, it was decided to attempt iodizing with a solution of iodine in the organic solvent carbon tetrachloride.

Recalling the fact that during sensitization of the silver plate by iodine vapors the plate passed through a definite series of color changes as the iodizing proceeded: pale straw, light yellow, gold yellow, orange, red, blue, purple, white, pale straw, etc., it was not difficult to determine the proper time to leave the silvered plates in contact with the iodine solution. The gold yellow color produced the most sensitive Daguerreotype plate.

By experimentation it was found that if a solution composed of 0.00007 molar iodine and 0.00002 bromine in carbon tetrachloride were allowed to remain in contact with a mirrored glass plate, the optimum sensitivity was approached in about fifteen seconds immersion; this sensitized surface appeared dull gold in color. At the end of 15 seconds the plate was removed from the iodine-bromine solution and fanned dry; the sensitizing was accomplished in the dark room under the light of the yellow safe-light. The sensitive plates were immediately placed in their holders and exposed as quickly as possible.

For proper exposure it was found that light colored objects were reproduced best at an exposure of 45 seconds, and extremely dark subjects at 90 seconds at an aperture of f/4.5 in full sunlight.

Development and Fixing

Immediately after exposure the plates were developed in a mercury fuming box as shown in Figure 1, and the method followed was essentially that of Daguerre. The progress of the development of the image was watched through the glass window on the side of the developing box. It usually appeared within six minutes, providing

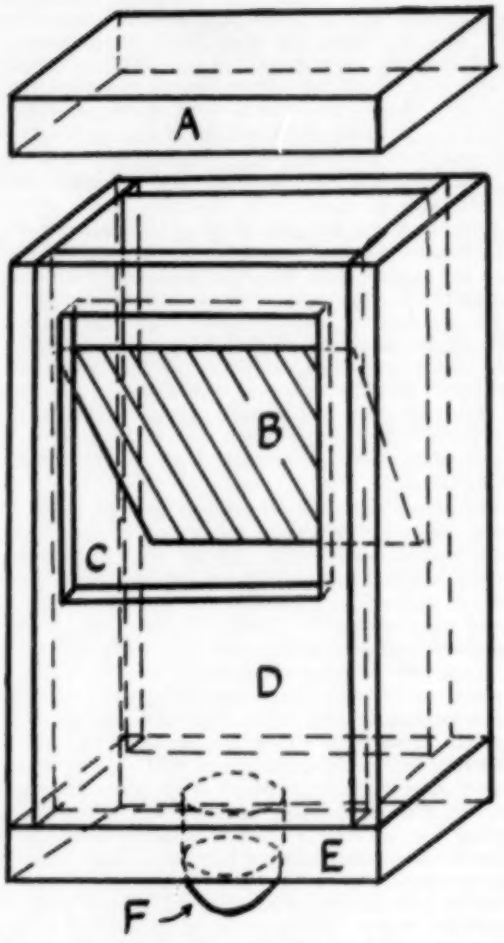


Fig. 1. Developing box for fuming exposed daguerreotype plates. A and E are the removable top and bottom, respectively. B is the exposed plate, held at a 45° angle for fuming. C is the glass window allowing inspection during the process. D is the fuming chamber. F is the iron dish containing mercury.

the exposure was sufficient. If the exposure was not sufficient to produce an acceptable image within six minutes of mercury development, that particular Daguerreotype was considered a failure and its image was promptly removed with nitric acid.

The developed Daguerreotype was placed immediately after its development into a solution of 0.5 molar sodium thiosulfate until the yellowish cast disappeared. Extreme care was necessary in removing the Daguerreotype from the sodium thiosulfate solution since at the slightest touch the silver would leave the glass support removing the image along with it. The transfer of the plate was accomplished with the fingers, and the plate was rinsed in water at room temperatures. If the wash water was too cold, a reticulated surface appeared and while this reticulation did disappear upon drying, it was not considered good technique to allow it to occur.

With the described process it was possible to achieve about 90% perfection.

References

1. Frazer, J. F., "Practical Description of the Daguerreotype," Journal of the Franklin Institute, Vol. 28, pp. 303–311 (November 1839).
2. Goode, W. H., "The Daguerreotype and its Applications," American Journal of Science, Vol. 40, p. 139 (December 1840).
3. Alpern, D. K., & Toporek, S., "Silver Plating from Acid Complex Iodide Baths," Transactions of the American Electrochemical Society, Preprint 74, No. 14 (1938).
4. Hiscox, Gardner D., Henley's Twentieth Century Home & Workshop Formulas, Recipes & Processes, The Norman W. Henley Publishing Co., New York, 1924, p. 476.
5. Adapted from a suggested procedure by Bovie, E., & Unger, P., "The Preparation of Pin-hole Free Silver Mirrors," Journal of Scientific Instruments, Vol. 28 pp. 68–70 (1951), C.A. 46, p. 6354.
6. Adapted from Strong, John, Procedures in Experimental Physics, Prentice-Hall, Inc., New York, 1945, p. 154 and Sen. P., & Rao, P. S., "Silvering on Glass," Journal of the Indian Chemical Society, Ind. & News Ed., Vol. 14, pp. 153–158 (1951), C. A. 46, p. 6354.
7. The Bureau of Standards reports that silver fulminate is less likely to occur when using a silvering solution which does not contain potassium hydroxide as one of its constituents, but the writer did not wish to take any chances. viz., Bureau of Standards Circular No. 389, p. 2 (1931).

NEW FAIRCHILD GUN CAMERA WITH AUTOMATIC EXPOSURE CONTROL

James B Moore*

A NEW TYPE of military target or "gun camera" has been developed by Fairchild Camera and Instrument Corporation of Syosset, New York for the U. S. Air Force. This camera, designated the "KB-5" automatically compensates for changes in illumination on the scene by means of an automatic control of the iris diaphragm.

These 16mm motion picture cameras, when installed on super-sonic speed jet fighter planes, can be used to record details of aerial combat. The importance of automatic exposure control when photography is attemped from a fighter plane is evident when it is realized that the nose of such a plane, engaged in a "dog fight," may be pointed at brilliantly sunlit sky one minute and a few seconds later at a densely shaded area of the earth. In the use of former cameras of this type, portions of the film would be greatly overexposed while other sections would be under exposed.

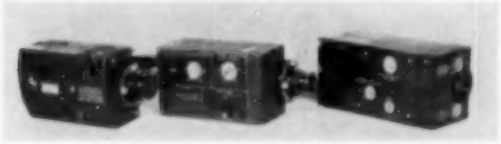


Fig. 1. The Fairchild family of military "Gun Cameras" includes, from left to right, the old N-6 GSAP (Gun Sight Aiming Point) camera, the N-9, and the new KB-5, with automatic exposure control. More than 150,000 of the old N-6 GSAP cameras were manufactured during World War II.

In the Fairchild KB-5 camera, the actual illumination received through the picture taking lens can be compared 64 times a second with the illumination from a reference lamp inside the camera. If there is a difference, the lens diaphragm is changed automatically to match the light level of the reference lamp which insures proper film exposure. This is accomplished by a closed loop system, employing a transistor servo amplifier. The rate of response to a change in light is rapid. The system will drive 6 lens stops in 1.8 seconds.

* Fairchild Camera and Instrument Corporation, Robbins Lane, Syosset, Long Island, New York.

Received 28 March, 1956.

required.

Fig. 2. The KB-5 camera with front plate removed to show the automatic iris diaphragm control. Two magnetic cylinders activate a "wiggler" system to control the rate and direction of change of the iris. Miniaturization of the camera mechanism includes the use of transistorized amplifiers.

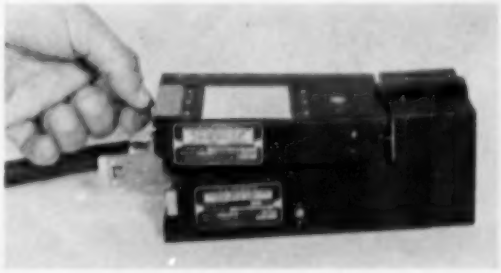


Fig. 3. Film magazines are loaded into a container which can be replaced with one hand by the airman in a matter of seconds whenever a fresh loading of film is required.

Another feature of the KB-5 is its extremely light weight. The camera, with a fully loaded magazine containing 50 feet of 16mm film, weighs less than $5\frac{1}{2}$ pounds.

New concepts of film handling are also employed. The unique film drive is contained in the film magazine itself. It is always engaged with the film and there are no clumsy claws to be bent or to lose contact with the film during the return stroke. Provision is made for daylight loading of the cameras, employing the Kodak 50-foot film magazine.

The shutter speed is $^1/_{200}$ of a second. This speed cannot vary with changes in frame rate as the shutter design entails two blades, both rotating in the same direction. The forward blade, or shutter blade, has an angular cutout of 92 degrees and rotates at a constant speed of 64 rps. The second blade has a 115 degree angular cutout and rotates at the same speed at the frame rate—64, 32 or 16 frames per second. With this arrangement the required shutter speed of $^1/_{200}$ of a second is maintained without the necessity of varying slit width as in the conventional type of shutter design.

MASKING FOR HALFTONE

Report of a lecture given by Mr. F. Pollak (Kodak Ltd.) on 22nd March 1956 at a meeting of the Scientific and Technical Group of the Royal Photographic Society of Great Britain in London. Contributed by Mr. R. E. Withrington, Hon. Sec. Received 23 April 1956.

The lecturer introduced his subject by summarising the contents of his earlier paper† dealing with the colour of multicolour halftone images. Owing to their dot structure the separate cyan and magenta components of halftone prints were more degraded than the corresponding ones of a continuous tone process employing the same inks. But the dot structure did not introduce a basic difference between Halftone and Continuous Tone processes as far as combination of the components into multicolour prints was concerned, both systems obeyed essentially the law of addivity of densities. It was, therefore, possible to write down a set of equations for halftone densities which expressed this law. These equations could be solved if use were made of the fact that the yellow ink used in practice was 'ideal' and the magenta ink transmitted (to all intents and purposes) all the red light. The resulting "masking equations" yielded information about the masking procedure which would give the colour correction required. The masks were not linear but bowed, being contrastier in the highlights and flatter in the shadows than linear ones, but of equal density range. They could be obtained by partly imagewise exposure and partly flash exposure and development to, gamma 1, the high gamma development ensuring the high highlight contrast, and the flash ensuring the low overall contrast. These masks would, therefore, subtract relatively more density from the lighter tones of the record with which they were bound up and thereby correct for the additional colour degradation of the light tones of the cyan and magenta halftone scales which the lecturer had mentioned (and illustrated with cyan scales) before.

The gradations of the masks and of the masked separations derived from these equations were however strictly limited to the case under discussion, which assumed that multiple reflections in the paper played little part and that solid densities were additive. The lecturer then turned to the practical applicability of his results and gave examples of measurements carried out on some recent printing experiments. These showed that with screen rulings of 85 lines/inch the degradation of a cyan halftone scale was only slightly less than calculated, that of the magneta scale agreeing with calculation. More serious deviation from 'ideality' occurred however, with the additivity of solids; in the printed example in particular, serious sub-additivity of the blue densities, less of the green densities and least of the red densities was encountered. But it could be shown by qualitative argument, and also by calculation, that this addivity failure affects halftone densities to an extent which decreases with decreasing dot size. This was confirmed from measurements of two-colour and three-colour step-wedges (printed with inks of solid densities of the order of 1.0) which showed that the density of the sum agreed almost exactly with the sum of the densities when this was less than about 0.9.

The lecturer summarized the various measurements by saying that with coarse screens the use of the procedure prescribed by the equations would result in the lighter parts of a grey scale being correctly reproduced, but the shadows lacking yellow and magenta. The lecturer showed two three-colour scales printed at 85 lines per inch, one (obtained from cyan, magenta and yellow scales of equal dot sizes) being brown, the other (obtained from the same cyan scale as before but with the magenta and yellow dot sizes reduced in accordance with the equations), being neutral. He stressed the fact that in printing the scale he departed from his equations insofar as the strengths of the magenta and yellow inks actually used were higher than those on which the calculations were based. This ensured neutral shadows (in both scales) and also affected, to a lesser extent, the lighter tones. As these appeared satisfactorily neutral, it could be concluded that if the assumed strengths of yellow and magenta inks had been used, the lighter tones of this scale would have been slightly lacking in yellow and magenta, i.e., would have been slightly "over-corrected". A slide in which the actual densities of the three progressives were plotted against the densities of the cyan progressive showed that the bowing required in the yellow and magenta printers was quite strong, being stronger in the shadows than indicated by the equations, owing to the additivity failure, and being somewhat less in the highlights owing to the interreflections in the paper.

The lecture ended with another printed example. In this case an 'Ektachrome' transparency was reproduced by means of (a) two linear masks, (b) two bowed masks. In each case the contrast of the transparency had first been reduced by a panchromatic contrast mask. The lecturer pointed out that he had followed the equations up to the point of making the uncorrected separations and the masks; he deviated from his halftone equations in the case of (b) and also from the linear equations in the case of (a) by "pulling up" the contrasts of the magenta and yellow printer so that their density ranges equalled that of the cyan printer. The dot size reduction of the two bowed printers was therefore less than theoretical. From the resulting (133 lines/inch) illustrations it could be seen that the two results differed in the expected direction, though the difference was not very great.

† Journal of Photographic Science, July–August 1955.